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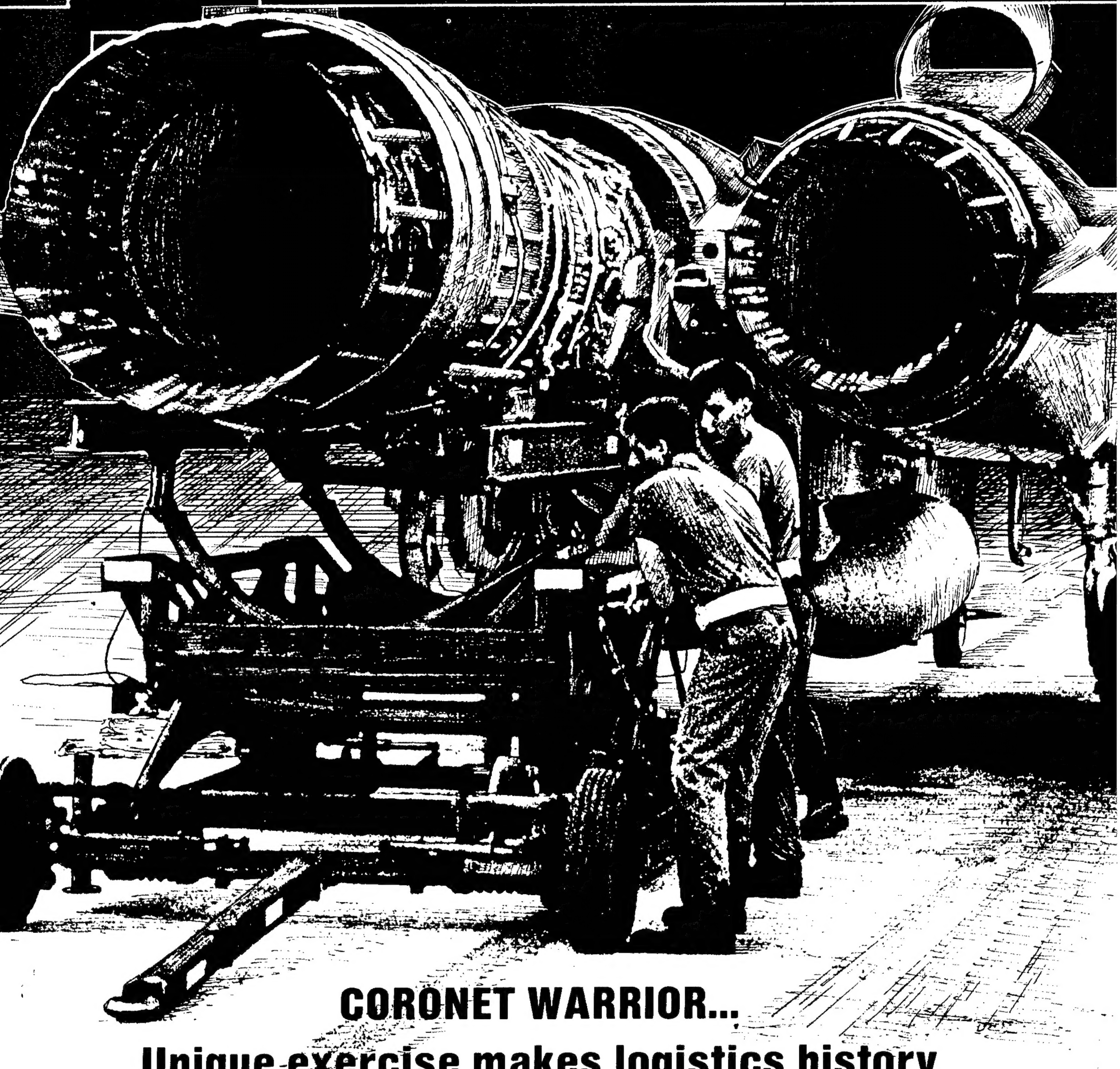

CORONET WARRIOR...

Unique exercise makes logistics history

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Purpose The *Air Force Journal of Logistics* provides an open forum for the presentation of issues, ideas, research, and information of concern to logisticians who plan, acquire, maintain, supply, transport, and provide supporting engineering and services for military aerospace forces. It is a non-directive, quarterly periodical published under AFR 5-1. Views expressed in the articles are those of the author and do not necessarily represent the established policy of the Department of Defense, the Department of the Air Force, the Air Force Logistics Management Center, or the organization where the author works.

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Coronet Warrior: A WRSK Flyout

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From 7 July to 6 August 1987, the Tactical Air Command conducted a flying exercise for 30 consecutive days—Coronet Warrior. This was the first time that such an exercise was conducted with primarily logistics objectives in mind. The first objective of the exercise was to validate and improve the Dyna-METRIC model used to evaluate units and to determine if the model could be used to build wartime spares requirements, such as war readiness spares kits (WRSK). Dyna-METRIC is currently used in the Weapon System Management Information System (WSMIS) as an analytical computer model to assess sortie generation capability. Because WRSK composition and assessments driven from that composition have been a continuing concern to the Air Force, Coronet Warrior provided a unique opportunity to learn more about spares support issues facing the logistics community and then offer solutions.

For Coronet Warrior, the 94 Tactical Fighter Squadron from Langley AFB, Virginia, consisting of a 24 PAA F-15C/D squadron, was isolated at home station in a simulated deployed environment. Spares, people, and equipment were limited to those authorized in the aviation package unit type code (UTC). The unit was supported by a remove/repair/replace (RRR) WRSK assessed at C-2 for sorties. The unit was tasked to fly "realistic" sortie rates for 30 consecutive days. A large cadre of data collection personnel were on-site to collect data on all the events. Post-exercise plans called for comparisons of *actual* versus *predicted* performance and included taking appropriate actions to improve the accuracy of the data bases used to support Dyna-METRIC model predictions. Collateral benefits included evaluating the ability of the Bendix Avionics Intermediate Shop (AIS) to support the unit as well as expanding the data base on electronic warfare (EW) equipment reliability and maintainability.

A thorough review of Dyna-METRIC modeling assumptions was done in conjunction with other exercise planning. This review focused on the specifics of how the model "fights the war." Essentially, Dyna-METRIC "fights" the war day-by-day, consuming parts based on the level of flying activity, and grounds aircraft when parts shortages occur. Two key assumptions of the model were evaluated during Coronet Warrior:

(1) Dyna-METRIC assumes repair is unconstrained by equipment and personnel.

(2) Cannibalizations are assumed to be instantaneous (actually accomplished overnight) and all "canns" are 100% successful.

Exercise Results

The unit was able to perform better than predicted. They actually flew 98% of their tasked sorties as compared to 91% predicted by the model. In terms of fully mission capable (FMC) aircraft assessments, the unit actually had 17 aircraft FMC at the end of the exercise vice 4 predicted by the model (Figure 1). The

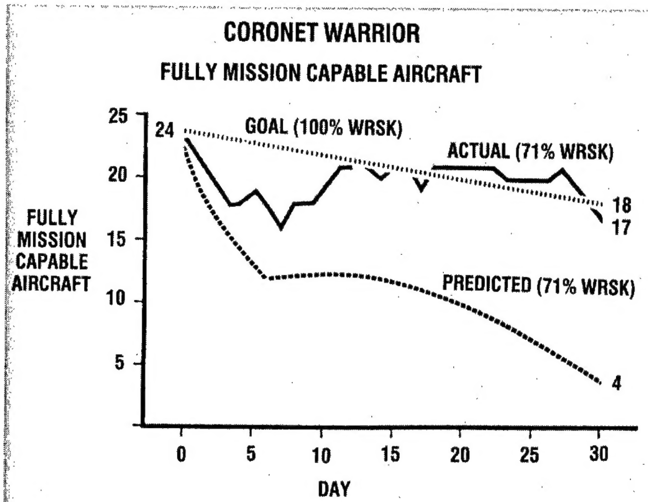

Figure 1.

analysis which followed the exercise focused on understanding the differences in actual versus predicted performance. Post-exercise analysis attributed these differences to:

(1) Demands for spare parts were less than expected.

(2) Parts were repaired faster and more successfully than predicted.

(3) Personnel were more innovative and performed better than predicted.

One of the unique features of the model is its ability to predict problem parts or "war stoppers." Although Dyna-METRIC is not a "war-predictor," it does have the capability to determine the contribution of aircraft spares to the sortie generation process. Figure 2 illustrates the difference in numbers of actual versus predicted war stoppers. These differences in problem parts drove the differences in FMC aircraft and sortie results. In general, problem parts did not cause the number of aircraft holes predicted by the model because there were fewer demands for parts than expected. On the other hand, the ALR-56 Receiver had more demands than predicted and ended the exercise as the number one problem.

To allow analysis of this demand variability, data collectors maintained meticulous records throughout the exercise on numbers of spares authorized and both predicted and actual consumption. As illustrated by Figure 3, the demand for spare parts was far less than predicted. Approximately 35% of the items in the WRSK were issued during the exercise. Figure 4 illustrates a comparison of the mean time between demands (MTBD) of Coronet Warrior, the D041 worldwide recoverable item consumption requirements system, and the D029 WRSK/BLSS computation system. Although demand rates at Coronet Warrior varied from those predicted by worldwide data, no single data source, including wing-level rates, was clearly the

CORONET WARRIOR WARSTOPPERS

PREDICTED & ACTUAL

COMPONENTS	DEMANDS PREDICTED	DEMANDS ACTUAL	D+30 HOLES PREDICTED	D+30 HOLES ACTUAL
MLG TIE	91	68	25	2
BAND 2 AMP	69	27	25	2
FUEL XMITTER	22	1	15	0
BAND 1 ANTENNA	16	8	15	7
EWWS R/T	41	11	12	3
BAND 1 AMP	38	9	9	0
039 PROCESSOR	10	51	0	0
081 PROCESSOR	13	45	0	0
INERTIAL UNIT	24	32	0	0
ALR-56 REC	4	24	0	6
BAND 2 OSC	55	24	0	0
011 XMITTER	8	22	4	2

Figure 2.

CORONET WARRIOR

DEMAND FOR REPAIRABLE PARTS

	NUMBER OF PARTS (AIRCRAFT ONLY)
WRSK AUTHORIZATIONS (100%)	3094
STARTING WRSK INVENTORY (71%)	2187

	PREDICTED	ACTUAL
DEMANDS	2162	946
ISSUES	1690	772
BALANCE (WITHOUT REPAIR)	497	1415

Figure 3.

CORONET WARRIOR WARSTOPPERS

DEMAND COMPARISON

(MEAN TIME BETWEEN DEMANDS IN HOURS)

COMPONENT	CORONET WARRIOR	DO-41	DO-29
MLG TIRE	52	66	36
BAND 2 AMP	65	68	45
FUEL XMITTER	3502	1471	166
BAND 1 ANTENNA	216	405	208
EWWS R/T	159	148	39
BAND 1 AMP	219	224	46
039 PROCESSOR	52	66	36
081 PROCESSOR	39	133	133
INERTIAL UNIT	55	78	75
ALR-56 REC	73	293	218
BAND 2 OSC	73	47	62
011 XMITTER	80	105	104

Figure 4.

best for forecasting demand. The greatest variability from "established" demand rates occurred in cases of wartime adjustment factor (WAF) and non-optimized (NOP) assets (cases in which demand per flying hour is either not sufficient to account for increased wartime use or is not an accurate measure of usage).

It is generally accepted that given reliable input data, the Dyna-METRIC model does an adequate job of predicting sorties and FMC aircraft for a remove-and-replace weapon system (a premise to be further validated during Coronet Warrior II). However, the ability of the model to represent the repair process accurately had not been tested. Thus, particular attention was given to examining in-commission, utilization, and the productive capacity of the AIS. Figure 5 graphically illustrates the productive capacity of the AIS. Note that the AIS, valued at $22M, was capable of returning $48M worth of assets to a serviceable condition. The station with the highest utilization and productive output was the TEWS Integrated Test Equipment (TITE) station, used for repair of electronic warfare assets.

Figure 6 illustrates some disparities between predicted versus actual units repaired and associated time frames. In nearly every

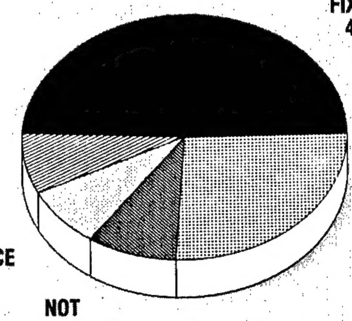

Figure 5.

CORONET WARRIOR

REPAIR CYCLE PRODUCTIVITY

COMPONENT	ACTUAL FAILURES	UNITS REPAIRED PRED	UNITS REPAIRED ACTUAL	DAYS TO REPAIR PRED	DAYS TO REPAIR ACTUAL	UNITS NOT REPAIRABLE PRED	UNITS NOT REPAIRABLE ACTUAL
039 PROCESSOR	51	8	49	4	1.0	3	0
081 PROCESSOR	45	9	43	6	1.0	3	1
IMU	32	14	29	5	3.1	11	3
BAND 2 AMP	27	42	23	6	4.2	2	0
BAND 2 OSC	24	41	5	6	3.1	2	0
ALR 56 REC	24	2	15	6	5.1	2	0
011 TRANS	22	5	20	4	1.8	1	0
IFF R/T UNIT	21	12	15	5	1.1	1	1
042 PROCESSOR	16	3	14	5	1.9	1	1
031 RADAR ANT	14	12	14	5	1.3	0	0
AIC	17	N/A	12	N/A	0.9	15	3

Figure 6.

case, the actual amount of time required to repair the highes demand components was considerably less than used in D029 Recall that the D029 demand/repair rates resulted in a predictior of only four FMC aircraft available at D+30. Conversely applying actual Coronet Warrior demand/repair experiences ir the model resulted in a prediction of 16 FMC aircraft at the enc of the exercise vice the 17 which actually occurred (Figure 7).

The previous figures highlighted significant disparitie: between predicted versus actual experience. The post-exercis analysis addressed the reasons for disparities and, consequently explained why the unit was so successful. In addition to th reasons previously discussed, the unit's superb performance wa: also a result of its innovative and aggressive approach in carryin; out taskings. Repair priorities were set correctly. Repair cycl management was motivated by criticality of asset in lieu of a unprioritized concern for simply turning out repairables

Mindsets were shifted to wartime production which facilitated a total integration of pilots and flight-line, repair, and supply operations. Inasmuch as the exercise was attempting to replicate actual wartime operations, peacetime repair constraints were removed (assets were repaired without regard for peacetime repair limitations). The only exceptions were components in safety of flight systems (flight controls, engine, etc.). Several innovative efforts on the part of maintenance personnel also contributed significantly to sortie production. These included "swapping out" critical components between test stations and use of grounded aircraft as "hot mockups" and engine test cells.

Cannibalization activity was closely monitored to evaluate the cannibalization assumptions of the model. A total of 426 cannibalizations actually took place vice the 429 predicted. This would lead one to trust the relative accuracy of the model for predicting cannibalizations. However, only 162 of the "canns" were to remove WRSK authorized parts from aircraft to restore another aircraft to FMC status. The other cannibalizations were either for non-WRSK items or to move holes, i.e., to consolidate parts shortages and maximize mission capability. With fewer demands, there are less holes and thus less need for

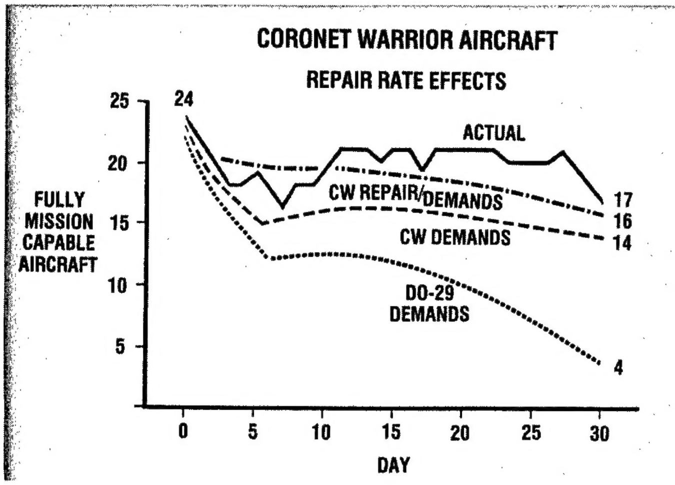

Figure 7.

cannibalization. Another interesting observation was the time required to perform cannibalization. Of the 426 total, 355, or 83.3%, were completed within 60 minutes or less. Total value of the 42 parts which took in excess of one hour was $1.9M. This suggests that configuration of WRSK should take ease of cannibalization/maintenance into consideration. Those assets which require extensive cannibalization time should be stocked at higher levels than those that require less time. Coronet Warrior experience did indicate that 424 of 426 cannibalizations were successful, with no damage to the part as a result of the removal or installation.

Determining EW spares requirements has been another issue which has plagued the logistics community for years. Current methodology for determining wartime EW spares requirements calls for the use of peacetime data to aid in the computation. This data is poorly defined and highly suspect. Additionally, during a peacetime training mission, there is little to fight against in the EW arena; therefore, pilots pay limited attention to these systems. A total of 659 sorties were flown in the exercise during which pilots were tasked to exercise the EW suite. A failure of either the radar warning receiver or the jammer was included in the Coronet Warrior electronic warfare results which are currently being studied in more depth.

Conclusions/Recommendations

Several conclusions were reached during this exercise:

• The human element continues to be one of the most critical factors in our warfighting capability.

• The current F15C/D aviation package can support the wartime mission.

• The AIS added greatly to the unit's combat capability, but both its utility and productivity by station warrant further study.

• The Dyna-METRIC model works well, but further refinement of repair logic may improve the models.

• Demand/break rate data bases need major review, especially in regard to NOP and WAF items.

• More accurate estimates of cannibalization and maintenance times must be included in stockage methodology. This would contribute to the development of better and less expensive WRSK.

• Electronic warfare equipment needs closer scrutiny and in-flight evaluation to be effective and supportable.

As a direct result of the exercise, Tactical Air Command made the following recommendations:

• Continue to use Dyna-METRIC methodology to compute spares requirements, and require a zero-based review of demand and fix rates to recompute F15 WRSK requirements for the worldwide fleet.

• Expand the utilization/evaluation of electronic warfare assets.

• Plan to conduct a similar exercise in FY88 involving the F16 since it will be the heart of the future fighter force and will rely on a remove/replace support concept during early phases of the war.

Post Exercise Activity
War Readiness Spares Kits

As a direct result of the valuable lessons learned from Coronet Warrior, TAC was in a unique position to redefine F15 WRSK composition. A series of analyses followed the exercise with five major goals in mind:

(1) *Scrub demand rates using Coronet Warrior as a benchmark.* Recognizing this exercise was a single data point, Coronet Warrior data was used only as an indicator of areas to investigate.

(2) *Reduce the D029 "tail."* As illustrated in Figure 8, the F15 WRSK (as computed by D029) had numerous line items with low authorized quantities. A very careful examination of these assets was made by both maintenance and supply personnel to ascertain the feasibility and ease of cannibalization. When a determination was made that cannibalization of a particular item was either very difficult and/or time-consuming, the item remained in the kit. Otherwise, the authorization was deleted under the premise that the asset could have been made available from the aircraft which were planned to be grounded for parts (the Direct Support Objective (DSO)). A scrub was also made of the 149 items which had demands less than six and the 414 items with no demands. The total dollar value of assets with either no demands or demands less than the DSO was $10.5M. The same logic was applied to a determination of the feasibility/ease of cannibalization, and authorizations were decreased accordingly. The outcome of these reviews (Figure 9) was a leaner, less expensive WRSK, yet one which is still capable of supporting expected wartime tasking.

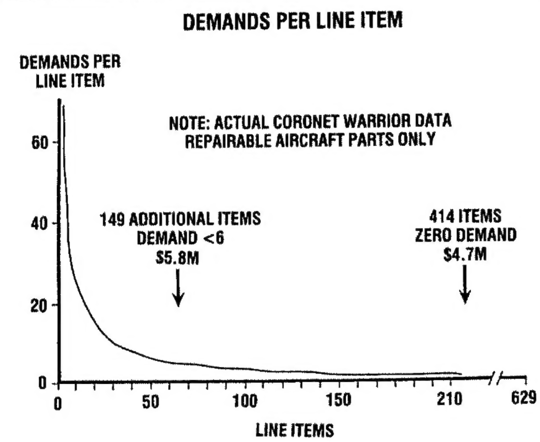

Figure 8.

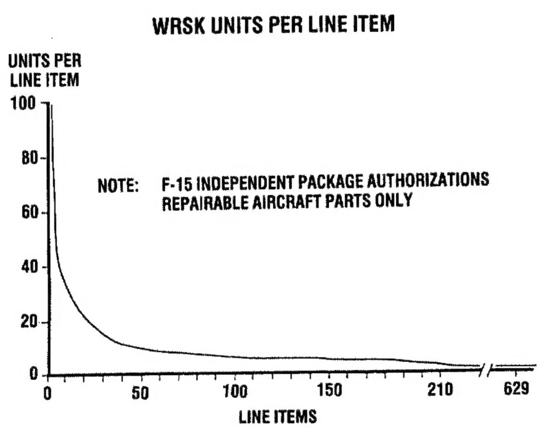

Figure 9.

(3) *Influence future buy requirements.* Applying the lessons learned and data adjustments from Coronet Warrior to the buy process will yield dollar savings. The ability to reduce both kit cost and size while maintaining required sortie generation capability made such an initiative a "must happen now" event.

(4) *Build squadron specific WRSKs.* The current D029 process essentially involves the development of a generic WRSK for a given model designation and series (MDS). Marginal analysis applies a safety level to expected demands to achieve the DSO. Building squadron specific kits requires extensive manual update of computer files; the current system is not very conducive to computing squadron specific kits. Thus, faulty tradeoffs are made which affect quantities authorized. Additionally, the cost benefits to be realized from squadron specific WRSKs make the initiative worthy of consideration and immediate implementation.

(5) *Provide feedback to the WSMIS Requirements Execution Availability Logistics Module (WSMIS-REALM).* WSMIS REALM is a major logistics enhancement designed to apply Dyna-METRIC methodology to all USAF WRSK/BLSS requirements. Although the mechanics of REALM are still being finalized, lessons learned from Coronet Warrior should influence development.

Initial plans called for briefing the results of Coronet Warrior at the 1987 F15 WRSK review and carefully studying the resulting D029 computations. Selected demand and repair rates were updated, low volume items were deleted, and electronic warfare factors were improved. Finally, a detailed comparison was made of an F15 kit computed using both D029 and Dyna-METRIC. This comparison led to a decision to recompute all TAC F15 contingency kits and pass the related data to Air Force Logistics Command (AFLC) to compute the buy kits. The resulting savings for TAC kits are timely in this period of tight budgets. These new kits are currently being fielded by Tactical Air Command and similar benefits are expected to be realized by Pacific Air Forces and the Air National Guard. DOD budget projections look bleak in the out-years and the ever-present need to do more with less is even more critical today than in the past. Initiatives such as Coronet Warrior will provide senior Air Force leaders the decisive edge they need to face the challenge.

Contractor Operated Parts Depot (COPAD)

Many military activities, and particularly those in the CONUS, may rely heavily on local procurement, a contractor operated parts store (COPARS), or a combination of activities to provide vehicle support. If you are receiving good support at an acceptable cost, that's great. However, if support is less than satisfactory for any number of reasons, you might want to try DCSC's COPAD. The process is simple and uses Military Standard Requisitioning and Issue Procedures (MILSTRIP). Merely complete a requisition with RIC S9C using project code JZO (alpha O not zero) for administrative vehicles, JZC for construction equipment, and JZM for MHE. We also recommend that CONUS activities use advice code 2A to avoid possible rejection by our system. In addition, we want to emphasize the use of A02 and A0B requisitions in lieu of A05. More information about our COPAD is contained in our COPAD Technical Guide dated January 1986. Request this guide by calling AV 850-2201 or commercial (614) 238-2201. Address written requests to the Defense Construction Supply Center, ATTN: DCSC-LRS, P. O. Box 3990, Columbus, OH 43216-5000.

Most Significant Article Award

The Editorial Advisory Board has selected "Hazardous Waste Law: A Survival Guide for Aircraft Maintenance Organizations" by 1st Lieutenant Craig E. Brackbill, USAF, as the most significant article in the Spring issue of the *Air Force Journal of Logistics*.

DISC Tightens the Screws on Fastener Fraud

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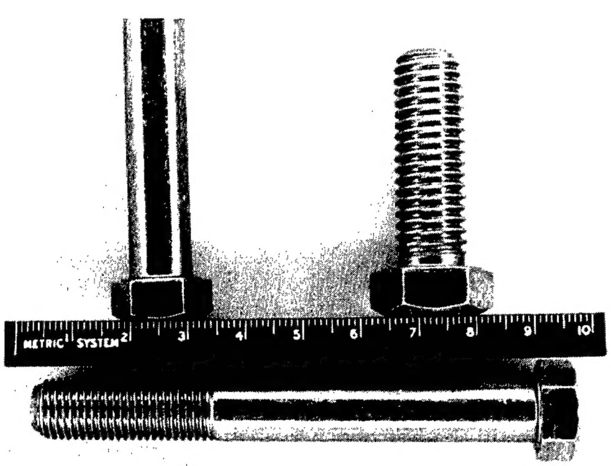
The Defense Industrial Supply Center (DISC) in Philadelphia, Pennsylvania, had a problem: buckets of bolts it had purchased for the military services were bogus. The Center discovered that unscrupulous suppliers and distributors were selling mismarked and improperly graded fasteners. With an inventory of more than 30 million items frozen and customer requisitions pouring in by the thousands each week, the Center used an innovative management approach to screen, segregate, and test the inventory, and lift its freeze in only six months.

Experts had predicted it would take at least three years to clean up the fastener inventory. In fact, what DISC—one of six supply centers managed by the Defense Logistics Agency (DLA)—achieved has yet to be equalled by the private sector, which is confronted with the same problem.

It all began in May 1986 at a meeting of the ASTM (American Society of Testing and Materials) Committee on Fasteners. At the meeting, the Industrial Fastener Institute (IFI) raised eyebrows when it described a year-long study that had disclosed fraudulent fasteners entering the country. The study established that high-strength, automotive-type bolts and screws were intentionally being mismarked with an incorrect material grade designation. Grade 8 fasteners, for example, were being replaced with Grade 8.2—fasteners of lower strength at elevated temperatures—which were marked with the Grade 8 designation.

In early July 1986, shortly after learning of the IFI findings, the Center issued a Government Industry Data Exchange Program (GIDEP) alert, developed a test program to assess the inventory, and issued orders to test samples using a nationwide network of independent test laboratories.



Counterfeit bolts are visually indistinguishable from properly graded fasteners.

By October 1986, the Center confirmed that the counterfeit material discovered in the private sector had also infiltrated DOD inventories. For the next eight months, DISC struggled to gain control of the situation as testing continued and criminal investigations began.

A Grade 8 fastener is subjected to a pull test, which determines strength properties.

Because of the magnitude of the problem, conventional means of dealing with the contaminated inventory could not be applied. In previous fraud cases, relatively limited quantities of suspect material were frozen while being traced to specific suppliers and contractors. The Center froze segments of the suspect inventory without crippling its effectiveness in supplying quality products to the military services. This time, however, with more than 30 million pieces of suspect inventory, the objective of screening the inventory while continuing to fill requisitions was impossible.

In June 1987, an order was issued to freeze the inventory, test it, and release only those items with correct material properties. This was a momentous decision: DISC had never before issued a directive affecting such a huge and active portion of its inventory.

Many voiced concerns about the potentially devastating effect of the directive and the ability of DOD to cleanse this large inventory in a reasonable amount of time. One news article estimated that it would take until the year 2000 to complete the job. In congressional testimony, an industry expert estimated it would require three years. In fact, however, these and other gloomy predictions proved to be unduly pessimistic.

To complete the inventory screening by the "end of the summer," conventional procedures were discarded. Teams of supply specialists were sent to depots throughout the country,

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The Professional Logistician

AN EDITORIAL

Are you a logistician? Are you a professional? What is logistics? What is the scope of logistics concerns? These questions were first posed by a small group of men from the aerospace industry in 1966.

Answering these questions led to the formation of the Society of Logistics Engineers. The first annual meeting of the Society was held in Huntsville, Alabama, on September 12-13, 1966, with Dr. Wernher von Braun as the keynote speaker. In his address Dr. von Braun challenged the fledgling society with these words: **"The training of logistics personnel is now a national problem"** and **"the need for more highly trained, capable logistics engineers is obviously great today, and the need will be greater in the future."**

The Society of Logistics Engineers, commonly known as SOLE, adopted a distinctive emblem which displays the Greek letters **alpha** and **omega.** These define the scope of logistics as being required, considered, and involved in the planning of every product and program **from the beginning to the end.** The emblem colors are also significant: the gold symbolizes the land; the blue, the sea; the white, the air; and the black, the outer reaches of space. Logistics is involved from concept to termination, from the beginning to the end, with every product in every part of our environment, whether it be on land, sea, in the air, or in outer space.

The needs defined by Dr. von Braun have not changed. In fact, as technology advances, the extent to which logisticians can be considered "capable" seems to decrease. The scope of logistics as reaching **from the beginning to the ending** is still not accepted as a management necessity by society at large, nor by the leadership of our government and corporate organizations.

We can define **logistics!** See the box for a definitive explanation of what constitutes the art and science of logistics. We can define **logistician**—as one who does logistics! What is not so clear is whether you and I, those who practice logistics, really qualify as professionals—one engaged in, or worthy of, the high standards of a profession. Sadly, most of us who read these words know only our own little corner. We may excel in supply, or maintenance, or technical data, or transportation, or reliability and maintainability in design, but we know not the spectrum of logistics—we are not professional logisticians.

The logistics profession has been correctly characterized as interdisciplinary. Logistics is not just a branch of engineering. It is not restricted to "business logistics." Logistics consists of a multiplicity of engineering, management, and technical functions integrated into a support system. It requires a complex team effort. The whole job simply cannot be done by any exclusive horizontal or vertical segment of the logistics field working on its own. In fact, the practice of logistics denies all elitist ideas and preconceived notions. The practice of modern logistics is the practice of **choice.** It identifies, quantifies, and evaluates trades-offs. It is a dynamic discipline, still unencumbered by dogma and outdated prescriptions.

In other professions, these considerations have led to the close identification of the professional person with a professional society. Interestingly, although there are several hundred thousand persons associated with logistics in industry and government, only about 10,000 belong to their professional society. Moreover, only about 1,500 of these are Air Force personnel.

Many professional societies, including the Society of Logistics Engineers, also have a professional certification program. This program is structured to assure that logisticians are exposed to the broadest possible perspective of logistics issues and skills, which are certified through an examination process, leading to designation as Certified Professional Logistician (CPL).

My concern arises from my vision of the future. In not too many more years, supply, maintenance, transportation, technical data, provisioning, and other type logistics jobs will disappear as we know them. In their stead we will be seeking broad gauged individuals who spend their working day in truly professional endeavors, delegating to computers the administrative and clerical functions which now account for much of our effort. It is these mundane tasks which have tended to keep our areas of responsibility narrow and compartmented. As the new era of information management dawns, those who know only a single specialty may find themselves on the outside looking in. Whether literally, or figuratively, those who do not qualify as professional logisticians will sense a lack of fulfillment.

If you are at least ten years away from retirement (and, for blue suiters, I mean away from ultimate civilian retirement, not near term military retirement), you need to begin now to broaden your horizons. There are many ways to do this. One way is to read and study professional journals, such as the *Air Force Journal of Logistics*. Don't just skim; read and absorb; and be sure you understand all of these good articles, not just those that may relate to your current job.

Do not neglect any opportunities to take relevant college courses. These may include statistics; management analysis; software engineering; business management; and, if you can find them, courses more directly relating to the functions of logistics such as distribution, transportation, and reliability and maintainability engineering. In my view, your primary concern should not necessarily be an additional degree, but the broadest possible education in the disciplines which are useful to the logistician.

But, how can we know what is relevant to a logistician, if we have only an imperfect understanding of what the profession of logistics is all about. That is where, perhaps, you might find an organization such as the Society of Logistics Engineers can make a contribution. Here, again, one needs to be cautious. Many chapters have deteriorated into a kind of "rotary club." The objective is not sociability, but learning. That is where annual symposia and various national workshops provide the greatest benefit.

Unfortunately, most of us never consider paying our own way to these various events. If we cannot justify it as directly relevant to our current job (so the government will pay), we do not even give serious thought to attending. It should be exactly the opposite. We want to learn that which we do not now know. We should consider paying our own way a sound investment in our own future.

In conclusion, I ask again: Are you a professional logistician? or, Are you just an employee/officer performing a logistics-like job? Do you know logistics? Do you know the full scope of logistics concerns with which your leadership (General Hansen, AFLC Commander; General McDonald, AF Deputy Chief of Staff for Logistics and Engineering; other logistics general officers; and senior civilian logistics executives) must wrestle? or, Are you satisfied to be a technical specialist knowledgable only in one narrow facet of logistics?

If you are not a professional logistician, I urge you to broaden your horizons and to undertake whatever may be required to change your self-image. If you are already a professional logistician, you have a responsibility to assist and encourage others in developing their professional potential.

(This Editorial contributed by Lloyd K. Mosemann, II, Deputy Assistant Secretary of the Air Force (Logistics), Department of the Air Force, who acknowledges his indebtedness to published materials of the Society of Logistics Engineers used in this Editorial.)

Logistics Defined

Although the term "logistics" has been around a long time, World War II established its most common usage. The word "logistics" comes from the Greek word which deals with mathematical calculations while its French usage relates to the supplying, quartering, and movement of troops. The United States gave the word a much broader definition, that of total support of a product during its life cycle. This includes such items as procurement, publications, facilities, manpower and training, maintenance, and transportation.

As defined by the Society of Logistics Engineers, logistics is the art and science of management, engineering, and technical activities concerned with requirements, design, and supplying and maintaining resources to support objectives, plans, and operations.

Logistics consists of *management, engineering,* and *technical activities.*

Logistics is not a function, task, process, or system. It is a broad field of endeavor consisting of many interdisciplinary activities. These activities constitute the art and science of logistics. Furthermore, the managerial, engineering, and technical activities involved do not constitute the art and science of logistics by themselves, but only when they are applied together to a composite of particular functions.

Logistics is concerned with analysis, synthesis, and definition of the resources needed to reach an objective or perform an operation under stated conditions. The total task of determining **requirements** is a planning function involving both strategic and logistic considerations. Allocation of the principal resources available, if less than those required, and evaluation of the impact of shortages upon major objectives, are primarily strategic responsibilities, not logistical functions.

The **design** function includes conceptual design through detailed design of products, systems, and services, including development, testing, and evaluation of the design. Logistics engineering is concerned with design for cost-effective supply and maintenance (supportability) in contrast to design for ease of manufacture or for effective operations.

Supply involves physical supply and distribution of all available resources; i.e., procurement, provisioning, recruiting, and training of personnel, production support, protective packaging, inventory management, traffic and transportation, order processing, and warehousing disposal. These are functions that create "time and place" utility in contrast to production operations that create "form" utility and marketing operations that create "ownership" utility.

Maintenance is broadly conceived as the conservation of facilities, products, manpower, systems, and services of producers and users, including the protection, preservation, and recovery of all resources employed.

Resources, such as materials, equipment, facilities, personnel, funds, and information, are all included. Logistics has been most often associated with material resources; however, many materials management techniques can also be applied to the management of manpower, money, and data. In addition, a ready supply of land, pure water, and clean air can no longer be taken for granted.

Logistics activities *support objectives, plans,* and *operations.*

Logistics activities complement and support strategy and tactics. They support production operations and field operations. Logistics activities support the goals, plans, and operations of systems.

You will notice the definition of logistics is conceptual, not functional. It was not intended to describe what a logistics manager, logistics engineer, or logistics technician does, or what he has to know, but only what logistics is. It does not specifically define business logistics, integrated logistics support, or any other specialized application of logistics. It presents a widely applicable description of all elements of macro- or micro-logistics. The definition therefore can be applied to the world or to the kitchen, depending upon whether the terms used to describe the elements of logistics are interpreted in a broad or narrow sense.

This definition does not introduce criteria for effective logistics performance. For example, it does not state that logistics is the integration of all the elements involved, because even though the elements are related in important ways, the degree to which these relationships are recognized in their management is not a determinant of the nature of logistics itself. The wrong thing in the wrong place at the wrong time is an equally valid description of one kind of logistics as the right thing in the right place at the right time is of another.

In summary, the business of logistics is big and complex, and everyone is dependent upon someone else. Roles are less obviously defined; therefore, all the elements are needed to define logistics. Delete or diminish one, and you impair or negate the others.

Armaments Cooperation and the Logistician: Boon or Burden?

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Introduction

With the rising costs of military systems accompanied by budgetary pressures to hold the line on defense spending, armaments cooperation—that is, the attempts to harmonize our development and acquisition of weapon systems with those of our allies—continues to receive a prominent hearing. For logisticians, whether they are concerned with initial procurement of a newly designed system or the daily support of existing systems, armament cooperation promises new methods of conducting business which call for informed practitioners and innovative techniques. Although NATO has 2½ times the Gross National Product (GNP) of the Warsaw Pact and about 1½ times the population, both sides commit approximately the same value of resources to defense, yet NATO produces far fewer of nearly every type of military equipment. Since the Warsaw Pact outproduces all of NATO by more than three-to-one in military aircraft and at least two-to-one in most other major weapons, the challenge is to improve our organization to maximize technological and industrial capabilities.[1]

Need for Standardization

Since the 1960s, NATO planners have been aware that alliance forces were impaired by a diversity of equipment unknown to the Soviet bloc militaries. As a result, improvements in the weapon acquisition process were sought to perfect the use of military resources for a better combat capability. A NATO war would involve an international coalition under a combined military command with the forces of the various partners conceivably merged into a single combatant unit or forced to rely on other nations for operational or logistics support. Operational effectiveness would therefore be enhanced by using similar procedures, tactical doctrines, equipment, and training. Early discussions of this issue often centered on how many different types of tanks, aircraft, artillery pieces, or missiles existed within the alliance, or how command and control of international forces were impossible because of the lack of compatibility of communications systems.

For the logistician, too, the lack of standardization engendered significant difficulties, since operational efficiency and effectiveness were impaired by logistics support problems arising from the variety of equipment employed within the alliance. Repair parts for dissimilar equipment could rarely be shared, and repair of equipment by the technicians of other nations was rendered virtually impossible due to lack of standard techniques, tools, or training. Varieties of fuels, munitions, and servicing equipment often restricted forces to their own logistics bases, thus degrading effectiveness as a fighting force.[2]

The history of armaments standardization has demonstrated the difficulties in attaining close cooperation between ourselves and our allies. There are many structural considerations that, on the one hand, press for further collaboration while, at the same time, impede successful achievement of cooperation.

For equipment standardization to succeed, the nations involved must first agree on equipment specifications. Because of different national military concepts and the consequent operational requirements, desired design characteristics often vary markedly. For instance, American requirements to support a worldwide deployment with extremes of temperature, climate, and terrain are excessive to the needs of military services facing a combat environment only in the European theater.[3] This naturally complicates cooperation in the early development phase of a system acquisition.

Besides the operational military benefits that would accrue, significant economic advantages also result from standardization. The principal areas of cost savings achieved through equipment commonality would be eliminating duplication of resources directed to armaments research and development (R&D), taking advantage of economics of scale by consolidation of production, and reducing support costs through use of comparable logistics services.[4]

While military and economic considerations of standardization are significant, one cannot lose sight of the political implications involved in choosing a military system, since defense decisions are also industrial policy decisions. For many countries a strong, independent arms industry is the cornerstone of a national feeling of well-being and a significant symbol of national sovereignty. Thus, there is a common urge to depend as much as possible on the local arms industry, even if this means supporting production runs that are too small to amortize the high R&D and nonrecurring production costs. Having a national defense industry is a source of pride and a symbol of thriving industrial capacity. In addition, military advantages are also cited in that local industry provides protection against external threats to security and guarantees against supply disruptions during periods of political tension, and also provides additional maintenance capacity.[5] For armaments cooperation to yield lowered weapon costs, it will be necessary to overcome this tendency towards national self-sufficiency and to consolidate as much as possible the development and production into a single effort.

Codevelopment

While maximum benefits are obtained through both the codevelopment and coproduction of a single system, these two aspects of acquisition are often treated as separate issues. The central economic objective of codevelopment is to reduce both the national development costs and risks through bilateral or

multilateral consortia of participating nations and manufacturers. For example, rather than each country trying to develop the next generation of fighter aircraft, there would be a pooling of technological resources aimed at developing a standard product with acceptable military characteristics for use by all allies in the consortium.

An important aspect of armaments cooperation is the possibility of acquiring new technologies by participating in collaborative development or production projects. This is especially true for countries seeking American technology, but is no less relevant for any nation seeking to learn from others who possess a technological advantage. In many instances, collaboration in research and development as a means of obtaining new technologies which can subsequently be applied to commercial products is preferable to coproduction under licensing agreements in which the transfer of technology may not be so significant nor will its application be so widespread. Especially in Europe where limited R&D investment and small production runs tend to place European firms at a disadvantage to American industry, the political reluctance to be seen as simply a subcontractor to the US is an immense hurdle to true collaboration.[6] The desire to have a fully developed, state-of-the-art arms industry has led many nations to emphasize their role in the development of the most sophisticated systems rather than being relegated to the production of technologically inferior systems. Increasingly, nations are unwilling to participate in projects which do not fully exploit their own R&D capabilities because of the strong reluctance to become dependent upon allies by relinquishing their own national capabilities. There is also little enthusiasm for pure specialization in any portion of a weapon system since that would limit the independence of a country's actions. The reluctance of governments to transfer full design responsibility to the firms of another nation also stems from this fear of technological dependence, yet impedes the achievement of the maximum benefits of collaboration which would take advantage of technological superiority of one of the partners.

Although codevelopment provides a ready answer to the problem of upwardly spiraling weapon costs, collaborative ventures nonetheless have their critics. From the point of view of the technologically advanced nations, the transfer of weapons technology in the spirit of armaments cooperation has been criticized by many as subsidizing foreign industry and creating potential competitors in the arms market. In addition, there is the fear that such transfers are tantamount to exporting jobs and creating an unfavorable balance of payments position.[7]

Critics of codevelopment also contend that in fact costs have not diminished but have risen as a result of having to deal with differences in language, norms, work methods, and geographic dispersion. The higher costs and longer development times will effectively mean decreased buys of the jointly designed weapon, likely curtailment or cancellation of other military programs, and delayed deployment.[8] These views, of course, would be directly opposed to the results anticipated by codevelopment in the first place.

Others are so convinced of American technological superiority that the US should be responsible for R&D of weapons involving complex technologies while other major industrial nations could logically develop less sophisticated equipment. Still other nations could supply basic small arms or radios.[9] However, today, such a stance belittles the technological capabilities of many of our allies and ignores the political implications such a policy portends.

Coproduction

Even without cooperative ventures in research and development, standardization can be accomplished by producing a standard weapon. Historically, this has been accomplished by allies purchasing the same weapon, often an American system. Foreign military sales (FMS) has been the principal method by which US equipment has been shared with friends and allies. However, with a ratio of US defense sales to Europe to US purchases in Europe of 5:1, a ratio which reached as high as 22:1 for individual countries, the European countries have balked at spending large portions of their defense budgets in the US.[10] This resulted in the demand for reciprocal purchases of defense equipment, an action often referred to as the "two-way street." Since the US has generally been unwilling to buy off-the-shelf European weapons, this reciprocity has more frequently been exhibited in the establishment of separate production of all or part of a system in Europe.

Collaborative production has been the most frequently used and the most successful aspect of armaments cooperation. Sharing production by means of licensing agreements between US manufacturers and foreign industry has been common since the production of the S-51 helicopter and the F-86 fighter in the late 1940s.[11] In its purest form, the purpose of coproduction is to extend the size of the defense market to include all the participants, permitting larger production runs with resulting lower unit prices as nonrecurring costs are allocated over a larger number of units. In coproduction, foreign manufacturers may produce all or a portion of the weapon developed by a single country. Fully integrated coproduction exists when each participating nation purchases the same system and produces parts for each other's weapons. The F-16 produced in the US, as well as in Belgium, Denmark, Netherlands, and Norway, is perhaps the preeminent example of this integrated collaboration effort. Although not common, the US has also produced weapons under license from foreign companies, the AV-8B being the most notable in recent years.

Because all countries are interested in maintaining full employment, there is pressure to spend government funds within its own territorial boundaries. Although this has long meant support for local industry, it has also been the impetus for demands for offsetting arrangements on major purchases from abroad. Demands for coproduction, then, are often primarily an attempt to ensure more work for defense industries and only secondarily a method of achieving weapons standardization. In fact, countries are often willing to pay a premium, compared to buying the system in its entirety from another country, in order to bolster employment in national industries and avoid dependence on foreign suppliers.[12]

Improved Support

Ultimately, standardization could lead to improved support. Redundant support facilities could be eliminated, numbers of line items of spare and repair parts could be reduced, and overall stock levels could be lowered if procedures for merged supplies could be arranged. In addition, there is opportunity for significant cost savings through these actions, such as a decrease in the unit costs of spares as increased numbers are procured to support the higher equipment population.[13]

NATO Commitment

Congress has long pushed for a commitment to standardization within NATO. The Culver-Nunn Amendment to the 1977 Defense Authorization Act[14] held that it was the policy of the US that NATO's equipment should be at least interoperable, if not standardized, and that DOD should strive to provide standardized equipment for our forces as a means of improving military readiness within the alliance. This notion was reaffirmed by the Roth-Glenn-Nunn Amendment of 1983[15] which became the foundation of our program of reciprocal memoranda of understanding (MOU). These memoranda provide for American and allied industries to compete for defense business with fewer obstacles on both sides.[16]

Former Secretary of Defense Caspar W. Weinberger emphasized that collective security depends upon greater defense-industrial cooperation throughout the alliance. To attain this goal, he directed the sharing of the best available technology among the alliance to avoid duplicative development costs, deployment of common or interoperable weapons, and coordination of research, development, production, and logistics support programs.[17]

Recent legislation has funded cooperative research and development projects within DOD and has spurred a new drive for arms cooperation throughout the military departments.[18] This new Nunn Amendment also promotes the examination of weapons manufactured by the NATO allies by providing for side-by-side testing of these weapons with comparable American ones. In addition, legislation in 1986 has also extended these provisions to weapons provided by major non-NATO allies.[19] Those latter allies have been designated by the Secretary of Defense to include Japan, Australia, Republic of Korea, and Israel. Amendments proposed by Senator Quayle in the same legislation similarly promote cooperative production ventures and even permit a foreign partner to contract on behalf of DOD.

As David Abshire, the permanent Representative of the US to the North Atlantic Council, pointed out, armaments cooperation is really only the engine that pulls other vital cars—such as common logistics support.[20] While armaments cooperation is usually understood in the context of systems acquisition, logistics support concerns are also receiving congressional attention. The FY 1987 Defense Authorization Bill also extends the NATO Mutual Support Act beyond the European NATO countries to improve support relationships with Canada, Japan, Republic of Korea, Egypt, and Israel. This provides new authority to develop policies for simplified acquisition and transfer of limited logistics support, supplies, and services between the US and these designated foreign forces.

Since the mid-1970s, supporters of collaborative acquisition policies have decried the multiplicity of similar weapons employed by NATO forces. Yet, today, after more than a decade of initiatives to remedy this situation, critics of lack of progress can still point out that "in seven different NATO countries there are 11 firms producing antitank weapons, 18 designing and producing ground-to-air missiles and 16 producing air-to-ground weapons."[21]

Thomas Callaghan, long a dominant voice in the call for increased cooperation between the US and its allies, criticizes NATO for what he refers to as "structural disarmament."[22] It is Callaghan's contention that all the national defense markets, including that of the US, are too small to permit the luxury of unnecessary duplication of development effort while continuing to manufacture weapons at less than optimum production rates. Because political considerations do not allow funding of weapons at the economically optimum production rate, fixed R&D and nonrecurring production costs are spread out over fewer units, wastefully raising unit costs. Callaghan's recommendation is for a "two-pillar North Atlantic defense market" in which allies on both sides of the Atlantic will abandon their own parochial national market structures and genuinely enter into a NATO-wide arms market which will permit weapons production at affordable prices. Under such a scheme, subcontractors on either side of the ocean would bid freely to prime contractors in either Europe or North American.[23]

Conclusions

In recognition of criticism such as Callaghan's—that our collaborative efforts have not really gone far enough—the Quayle-Nunn legislation is pushing DOD towards greater and more significant involvement in joint efforts with our allies, especially in emphasizing codevelopment of systems which will be used by all parties. Air Force programs such as the Modular Standoff Weapon (MSOW), Multifunctional Information Distribution System (MIDS), NATO Identification System (NIS), and Enhanced Fighter Maneuverablity are all proceeding under the auspices of the Nunn Amendment which requires codevelopment whenever possible. It is logical to expect that, if codevelopment results in a successful product, meaningful coproduction will follow.

Defense contractors, too, must face the realities of the international marketplace if they expect to develop weapons for export. The ability to compete in selling the next generation fighter in Europe will surely depend on the willingness to share in its development with several European countries. Failure to come to grips with how to transfer the necessary technology may well exclude American aerospace manufacturers from this sizable market, negating the logistical and cost benefits which might otherwise be achieved.[24]

For the logisticians, then, this renewed emphasis on armaments cooperation will have an impact on the acquisition and support of new systems. The acquisition logistician will be faced with the need to consider foreign products and foreign proposals, thus adding new twists to the procurement process. Dealings with both American and foreign manufacturers on designated projects may well be covered by a memorandum of understanding which will permit or require deviations from standard acquisition procedures. Logically, as other nations enter into this process, contractors will find it advantageous to team with foreign partners. Eventually, it is possible that the actual contracting may not be done in the US at all, but will be assigned as the responsibility of one of our allies.

Of course, these changes will also affect the support logistician. For example, if systems are produced in other countries, the source of spare parts may well be overseas. This may require the development of improved techniques for ordering, in effect reversing some of the procedures found in our foreign military sales system today. Additionally, the deployment of common equipment will make host nation support the logical answer to support difficulties, and this will spark the search for continued improvement in providing mutual support.

For everyone involved in the acquisition or support of our weapon systems, the success of these new armaments

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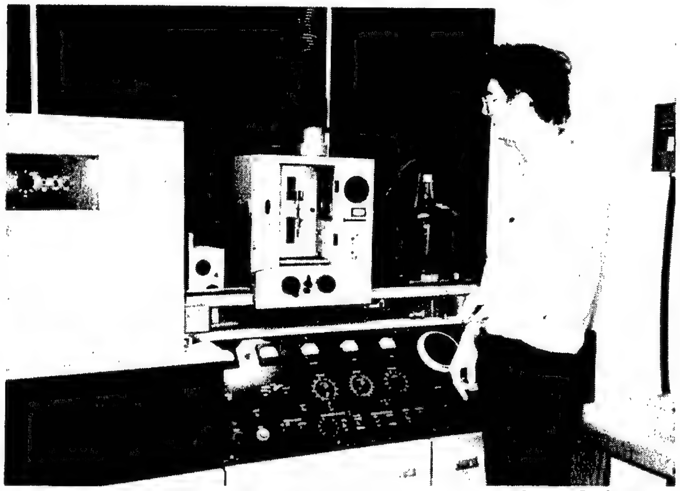


A technician prepares a specimen for spectroscopic analysis to determine its chemical composition.

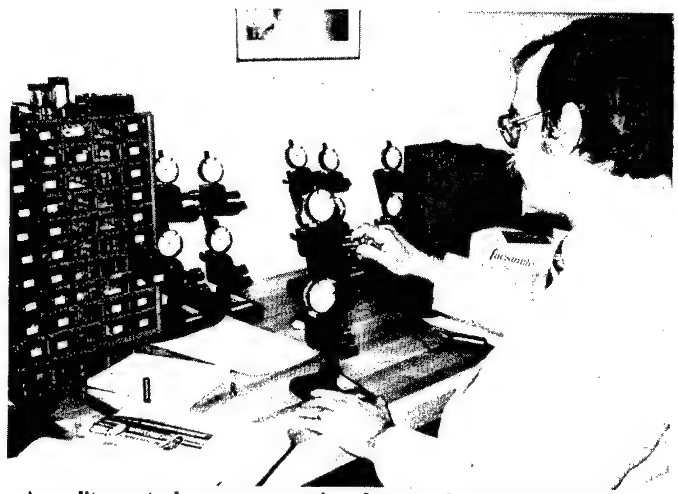
where they selected samples from various contracts and forwarded them to 30 different laboratories for testing. On average, it took the independent laboratories nine days to feed results back to DISC's engineering staff for evaluation. After the evaluations were forwarded to Supply, the loop was closed and the inventory completed—a mere six months after stock was frozen. In all, more than 1,200 contracts were reviewed and more than 12,000 samples tested and evaluated.

Although the main thrust was the inventory assessment, other important activities were concurrently pursued. Customers were continuously apprised. Detailed messages to dozens of customers and activities were issued. And when bogus fasteners were detected, information was fed to criminal investigators and prosecutors for legal action. As a result, the Grade 8 fastener investigation has led to proposed debarments of four suppliers, and criminal and civil suits are underway.

A technician conducts a microhardness test.

Equally important, however, were measures taken to prevent a recurrence. Contract clauses accentuating quality standards were developed and implemented. To assure product traceability, a clause was written requiring listing of manufacturers' symbols with the American Society of Mechanical Engineers. Alerts were issued to Defense Contract Administration Services offices, and information papers were transmitted to the entire quality-assurance community.

Finally, action was taken to ensure that counterfeit products would have no chance to re-enter the system. Detailed arrangements were made to collect all defective parts and smelt them down in the presence of government witnesses. Disposal is imminent, with only minor details on retention of samples for evidence to be worked out with the U.S. Attorney's Office and the Defense Criminal Investigative Service.



A quality-control manager examines fastener thread-measurement gages.

What is the fastener situation today? The improvement has been dramatic. When the inventory was frozen in June 1987, there were a number of active contracts whose products had not yet been delivered. These contracts were flagged so that, when the products arrived at the depots, they were held aside until a sample could be tested and evaluated. Results from almost 200 contracts show that the material rejection rate has dropped from 30% to 6%. With the new contractual and inspection safeguards in place, this rate should continue to improve.

Unfortunately, Grade 8 fraud may not be the last of its kind; in fact, other commodity inventories are currently being assessed. But bolstered by the lessons learned from the Grade 8 case, DISC is confident that any similar problem is manageable—and more likely to be avoidable.

"If you are going to report on something, don't take the word of other people. Go out and eyeball it and see and talk to people. You get a far different feeling for the problem and the situation."

Maj Gen Edward G. Lansdale
Military Review, May 1988

Manpower—The Critical Resource: A New Statistic for Reliability and Maintainability Application

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Introduction

Technology increases exponentially, and with it comes complexity for newly acquired DOD systems. Maintainers are no longer dealing with a few simple components per system. Every component of a given system has its own reliability such that the product of the component reliabilities equals system reliability. Simply stated, more components means more things can break, causing an increased burden on maintenance support, and subsequent lower system reliability. Today's systems have a greater number of components and, until recently, the potential for increased support burden and associated diminished reliability was overlooked. Enter the R&M 2000 initiative, enacted by the Secretary of the Air Force early in 1985, whose goals are to:

(1) Increase warfighting capability.
(2) Increase survivability of the combat support structure.
(3) Decrease mobility requirements per unit.
(4) Decrease manpower requirements per unit of output.
(5) Decrease costs.

Air Force contracts now require that reliability, maintainability, and supportability considerations be designed into a product. But how can we be certain these considerations are actually in the product? The developer must be required to guarantee a certain level of maintainability, supportability, and reliability subsequent to the actual purchase.

If you have been to any R&M symposiums lately, you have no doubt seen a number of "models" related to R&M design. All these models incorporate statistics such as mean time to repair (MTTR), mean time between failures (MTBF), and mean man-hours to repair (MMR). Rarely are these statistics scrutinized for inherent problems and many of them have shortcomings in certain applications. Beyond the technical problems, which we will discuss, none of the resulting statistics are a true measure of any of the R&M 2000 goals. Instead, they are incorporated into R&M models which in turn yield estimates on the success of meeting R&M 2000 goals. Might there be some simple statistics that do measure R&M 2000 goals directly? Yes, there is one. In this paper, we examine several of the old, taken-for-granted statistics, expose their shortcomings, and offer a new alternative. This new statistical alternative simply sums across components and maintenance levels to yield meaningful support burden numbers for managers at every maintenance level. It is a "big picture" statistic without the shortcomings of currently used statistics—an easily understood statistic that buyers could require sellers to use in their reliability analyses during the acquisition cycle. To satisfy R&M 2000 goals, we must be able to measure them. This statistic is an exact measure of goal number four: manpower requirements per unit of output. In fact, this statistic has allowed us to produce an optimization scheme—not only can we decrease manpower requirements per unit of output, we can minimize it! We are out to minimize the most crucial of all wartime resources—MANPOWER. What follows describes the measure of goal number four of R&M 2000 and the means to attain the goal.

R&M Measures

Perhaps the most commonly used supportability statistic is mean man-hours to repair (MMR). It is a simple measure of the expected man-hours required to repair a given component. Let a simple system X be composed of two components: X-1 and X-2. Observing one month's worth of data, suppose the following is observed:

$$\text{MMR X-1} = \frac{\text{100 total man-hours}}{\text{20 failures}} = \text{5 man-hours/failure}$$

$$\text{MMR X-2} = \frac{\text{44 total man-hours}}{\text{4 failures}} = \text{11 man-hours/failure}$$

How could the system X support burden be measured? First, recognize the simple sum of component MMRs is meaningless. The simple sum of 5 + 11 would be the expected man-hours required to repair system X if *both* X-1 *and* X-2 failed simultaneously. This is not the real-world consideration. The real-world support burden consideration is the required man-hours to repair system X in the event that *either* X-1 *or* X-2 fails. The logical way to put these component MMRs together is to add the total hours and divide by the total failures:

$$\text{MMR system X} = \frac{\text{144 total man-hours}}{\text{24 failures}} = \text{6 man-hours/failure}$$

This does make sense and gives a logical summary; however, it has its mathematical shortcomings. We have just added numbers of uncommon denominators by summing the numerators and dividing by the sum of the denominators—the very process your fourth grade teacher warned against! Let me expound upon the mathematical error:

> Two players are vying for the ninth position on a given professional baseball team. The day before the first game the coach states that since the players appear to be equivalent, he will simply determine the ninth player by the previous year's batting average. Player A batted 368 the previous year while player B only batted 321. Come game #1, the coach calls player B to the ninth position. When questioned by player A, the coach explained that the opposing pitcher is left-handed and last year player B batted 556 against left-handed pitchers while player A batted 500 against left-handed pitchers. Recognizing that the team would face more right-handed pitchers throughout the rest of the year, player A argued no further. Come game #2, the coach again called player B to the ninth position, even though the opposing pitcher pitched right-handed. In answer to player A's protest, the coach merely

explained that last year player B batted 300 against right-handed pitchers while player A batted 250 against right-handed pitchers. Player A's overall batting average from the previous year was better than player B's overall batting average from the previous year, even though player B was better against *both* left- and right-handed pitchers. How can this be?

	PLAYER A	PLAYER B
Against left-handers:	18/36 = .500	5/9 = .556
Against right-handers:	10/40 = .250	30/100 = .300
Total:	28/76 = .368	35/109 = .321

Table 1.

It is true. This really does happen (see Table 1). It is merely a result of summing numbers of uncommon denominators. Inversions like this occur because of underweighting or overweighting certain fractions. The contrived example in Table 2 highlights the effects of improper weighting.

	PLAYER A	PLAYER B
Against left-handers:	0/5 = .000	1/95 = .011 (better)
Against right-handers:	94/95 = .989	5/5 = 1.000 (better)
Total:	94/100 = .940	6/100 = .060 (worse)

Table 2.

The same kind of inversion can exist when component MMRs are put together in this manner. While other component MMRs remain unchanged, the MMR of one component could be reduced significantly and reflect as an increased system MMR. Contrast the effect of the improved MMR of component X-1 on system X MMR shown in Table 3.

	OLD DATA	NEW DATA
MMR X-1:	100/20 = 5	18/6 = 3 (improved)
MMR X-2:	44/4 = 11	44/4 = 11 (unchanged)
X system:	144/24 = 6	62/10 = 6.2 (worse)

Table 3.

It should be apparent that MMR calculations have serious pitfalls. MMRs cannot be simply summed across components; and, if they are "put together" across components, inversions may occur. Most commonly used maintenance statistics have similar shortcomings.

Mean Man-hours Per Unit Time or A New Statistic

Mean man-hours per unit time (MMUT) of system/equipment/line replaceable units (LRU) is a measure one may use to evaluate manpower requirements per unit of output (R&M 2000, goal #4). We have created this statistic so it is easily summed across components without inversions. It is also summable across a multiple tiered maintenance scheme such as the one in use within the Air Force (organizational, intermediate, and depot levels). Technically,

$$\text{MMUT} = \frac{\text{failure rate}}{\text{repair rate}} = \frac{\text{1/mean time between failure (MTBF)}}{\text{\# actions/total maintenance man-hours (MMH)}}$$

$$= \frac{\text{1/MTBF}}{\text{1/MMR}} = \frac{\text{MMR}}{\text{MTBF}}$$

The F-16 centralized data system (CDS) uses a similar statistic to MMUT: mean man-hours per flying hour (MMHPFH). The basic difference between MMUT and MMHPFH is the way man-hours are allocated within each statistic. Within MMHPFH, man-hours are attributed to the LRU on which they were performed. LRUs are simply components of a given system. This method of attributing man-hours can mask the appearance of problem LRUs. Often a "problem LRU" will fail and not be immediately isolated. This expands man-hours searching the system and bench-checking other LRUs. These man-hours within MMHPFH are attributed to system categories and LRUs that have not failed. Within MMUT, *all* man-hours are attributed to causing LRUs, thereby eliminating the "system" category for man-hours. MMHPFH has its place—it is the number of hours you can expect to work on certain LRUs; however, the real support burden is caused by item failures and these are directly measured by MMUT.

MMUT can readily be applied to give the support burden "big picture" for any item to the maintenance manager at any one, or any combination, of the three maintenance levels (organizational-level = o-lvl, intermediate level = i-lvl, depot level = d-lvl). (See Table 4)

It should be noted, before we proceed with specific examples, that the "traceability" of a failed item through all maintenance levels is a fundamental assumption of the procedure. This is a very important and not unreasonable assumption and is accomplished in practice by sorting maintenance data by job control numbers.

TYPE I ACTIONS

$$\begin{array}{ccccccc}
\text{MMUT}_{\text{LRU-1}} & = & \text{MMUT}_{\substack{\text{o-lvl}\\ \text{LRU-1}}} & + & \text{MMUT}_{\substack{\text{i-lvl}\\ \text{LRU-1}}} & + & \text{MMUT}_{\substack{\text{d-lvl}\\ \text{LRU-1}}} \\
+ & & + & & + & & + \\
\text{MMUT}_{\text{LRU-2}} & = & \text{MMUT}_{\substack{\text{o-lvl}\\ \text{LRU-2}}} & + & \text{MMUT}_{\substack{\text{i-lvl}\\ \text{LRU-2}}} & + & \text{MMUT}_{\substack{\text{d-lvl}\\ \text{LRU-2}}} \\
+ & & + & & + & & + \\
\vdots & & \vdots & & \vdots & & \vdots \\
\hline
\text{MMUT}_{\text{SYSTEM}} & = & \text{MMUT}_{\substack{\text{o-lvl}\\ \text{SYSTEM}}} & + & \text{MMUT}_{\substack{\text{i-lvl}\\ \text{SYSTEM}}} & + & \text{MMUT}_{\substack{\text{d-lvl}\\ \text{SYSTEM}}}
\end{array}$$

Table 4.

Note from Table 4 that item managers at all three maintenance levels have meaningful support statistics for each LRU as well as a system support statistic! To calculate MMUTs at each level, MMRs and MTBFs are required.

MMRs are calculated by ascribing man-hours to failure causing LRUs as previously mentioned. There is a problem in calculating MTBFs at the i-lvl and d-lvl, since every failed unit may not require maintenance at i and d levels. In the context of the notation used in Table 4,

$MTBF_{LRU\text{-}X}$ is known.

$MTBF_{\substack{o\text{-}lvl\\LRU\text{-}X}}$, $MTBF_{\substack{i\text{-}lvl\\LRU\text{-}X}}$, $MTBF_{\substack{d\text{-}lvl\\LRU\text{-}X}}$ must be calculated.

An example is the simplest means to describe the calculation:

Given:

$MTBF_{LRU\text{-}X} = 250$ hours

LRU-X actions = 90, resulting in 90 LRU-X o-lvl, 78 LRU-X i-lvl, and 28 LRU-X d-lvl actions.

Find:

$MTBF_{\substack{o\text{-}lvl\\LRU\text{-}X}}$, $MTBF_{\substack{i\text{-}lvl\\LRU\text{-}X}}$, $MTBF_{\substack{d\text{-}lvl\\LRU\text{-}X}}$

Solution:

90 actions × 250 hours = 22,500 hour period.

$$MTBF_{\substack{o\text{-}lvl\\LRU\text{-}X}} = \frac{22{,}500}{90} = 250.00 \text{ hours}$$

$$MTBF_{\substack{i\text{-}lvl\\LRU\text{-}X}} = \frac{22{,}500}{78} = 288.5 \text{ hours}$$

$$MTBF_{\substack{d\text{-}lvl\\LRU\text{-}X}} = \frac{22{,}500}{28} = 803.6 \text{ hours}$$

These MTBFs are now ready to be combined with their corresponding MMRs in order to calculate MMUTs. To demonstrate the reporting value of this new statistic, Table 5 contrasts the new analysis method described in this article with the old reporting procedure.

FAILURE #	o-lvl MMH		i-lvl MMH		d-lvl MMH	
	New Mthd	Old Mthd	New Mthd	Old Mthd	New Mthd	Old Mthd
1	7.2	1.5	8.0	*	24.0	*
2	15.0	6.0	12.9	10.2	12.0	*
3	20.0	12.0	68.2	*	22.0	*
4	0.0	*	10.0	*	0.0	*
5	12.0	3.0	20.6	16.4	0.0	*
6	15.0	3.0	12.4	*	0.0	*
7	15.0	3.0	32.0	*	0.0	*
8	9.0	5.0	10.5	*	12.0	*
9	3.9	*	4.0	*	0.0	*
10	4.8	*	9.0	*	20.7	*
11	12.0	2.0	8.2	*	11.0	*
12	15.0	*	0.0	*	0.0	*
13	27.0	*	29.0	*	0.0	*
14	3.8	1.0	11.0	*	0.0	*
15	2.0	*	4.3	*	0.0	*
16	53.0	12.0	7.0	6.2	0.0	*
17	10.5	7.5	5.1	*	0.0	*
18	30.0	3.0	7.0	*	0.0	*
19	10.0	*	7.4	*	0.0	*
20	1.0	*	17.4	14.9	12.0	*
21	64.5	20.0	43.2	38.2	0.0	*
22	4.0	*	15.0	*	0.0	*
23	8.0	2.0	1.0	*	0.0	*
24	19.0	7.0	4.1	3.3	21.5	*
25	36.0	1.5	3.5	*	0.0	*
26	24.0	8.0	14.4	12.4	0.0	*
27	40.0	24.0	12.3	*	0.0	*
28	13.5	1.5	0.0	*	0.0	*
29	4.5	*	10.0	*	0.0	*
30	16.5	3.0	13.0	*	0.0	*
31	18.0	4.0	10.7	*	0.0	*
32	4.0	2.0	13.4	*	0.0	*
33	9.0	3.0	8.0	*	0.0	*
34	3.0	*	12.0	*	0.0	*
35	6.0	3.0	7.0	*	0.0	*
36	10.0	6.0	12.0	*	0.0	*
37	27.0	10.5	8.0	*	0.0	*
38	33.7	4.0	44.2	5.0	0.0	*
39	19.5	4.5	10.0	*	0.0	*
40	3.8	*	25.3	*	0.0	*
41	21.0	3.0	7.0	*	0.0	*
42	2.0	*	49.8	*	0.0	*
43	3.0	*	36.0	*	0.0	*
44	22.5	6.0	25.4	*	0.0	*
45	6.0	1.0	6.0	*	0.0	*
46	8.0	2.0	3.2	*	0.0	*
47	19.5	*	13.6	*	0.0	*
48	2.0	*	23.0	*	0.0	
49**		3.0		8.0		0.0
50**		5.0		8.0		0.0

** indicates "old method" data that was attributed to another causing component under the "new method."

Table 5.

Hidden Support Burden

The data given in Table 5 was drawn from the Dynamics Research Corporation F-16 centralized data system. It is Type I maintenance data recorded from July - December 1986 at Nellis AFB, Nevada, on the F-16 Flight Control Computer (Work Unit Code 14AAO). The "old method" for maintenance man-hours (MMH) is the ascribing of man-hours to components upon which the man-hours were spent; whereas, the "new method" for MMH is the ascribing of man-hours to components which caused the failure inquestion. The * indicates "old method" man-hours that are the same as "new method" man-hours.

Table 6 represents the summary statistics on both "new" and "old" methods.

Notice the large difference in total man-hours at the o-lvl between "new" and "old" methods (Table 6). 427.7 man-hours, or 9.2 man-hours per repair which were directly caused by this LRU, have previously not been associated with this LRU at the o-lvl! This may be a "problem LRU" which no one knew about—"old" method data hid the support burden caused by this LRU.

	o-lvl		i-lvl		d-lvl	
	New Mthd	Old Mthd	New Mthd	Old Mthd	New Mthd	Old Mthd
# actions	48	50	46	48	8	8
MMH	714.2	286.5	715.1	673.9	135.2	135.2
MMR	14.9	5.7	15.5	14.0	16.9	16.9

Table 6.

Let's look at the commonly reported maintenance statistics for support burden under the "old" method and contrast it with maintenance support burden statistics that should be reported under the "new" method, Tables 7 and 8:

"OLD" METHOD REPORTED STATISTICS

LRU 14AAO	TOTAL	o-lvl	i-lvl	d-lvl
# actions:	50	50	48	8
Total man-hours:	1095.6	286.5	673.9	135.2
MMR:	21.9	5.7	14.0	16.9
MTBF:	250.3	--not reported this method----		
MMUT:	---- not reported this method------			

Table 7.

"NEW" METHOD REPORTED STATISTICS

LRU 14AAO	TOTAL	o-lvl	i-lvl	d-lvl
# actions:	48	48	46	8
Total man-hours:	1564.5	714.2	715.1	135.2
MMR:	32.6	14.9	15.6	16.9
MTBF:	250.3	250.3	261.1	1501.5
MMUT:	.130 =	.059 +	.060 +	.011

Table 8.

Table 7 assumes o-lvl, i-lvl, and d-lvl MMRs are looked at collectively, which is often not the case. In most situations only the o-lvl MMR is reported to reflect the support burden. This gives the impression that an F-16 Flight Control Computer failure generates 5.7 hours of support burden when in reality it generates a whopping 32.6 hours of support burden (Table 8). Referring back to Table 7, even if the Total MMR for LRU 14AAO is reported across maintenance levels as 1095.6 total man-hours divided by 50 actions, or MMR = 21.9 hours of support burden per failure, a considerable difference from the correct figure of 32.6 hours remains (not to mention the fact that inversions occur when MMR is taken across levels).

Conclusions drawn from the "old" method depicted in Table 7 will simply not reflect the real support burden situation. One may ask: What is the man-hour distribution on this LRU across the maintenance levels? Drawing data from Table 7:

Sample calculation:

$$\text{i-lvl: } \frac{673.9 \text{ total man-hours @ i-lvl}}{1095.6 \text{ total man-hours @ all levels}} = 61.5\%$$

Given the data from Table 7 and the method of calculation, it could be concluded that for this LRU 26.2% of man-hours are spent at the o-lvl, 61.5% of man-hours are spent at the i-lvl, and 12.3% of man-hours are spent at the d-lvl. Using data which is appropriately organized in Table 8 and using the same method of calculation, a drastically different answer to the same question is obtained. That is, for this LRU, 45.7% of man-hours are spent at the o-lvl, 45.7% of man-hours are spent at the i-lvl, and 8.6% of man-hours are spent at the d-lvl. Erroneously organized data will simply yield erroneous conclusions.

In addition to false impressions, the primary shortcoming of the "old method" is that it is a deadend. There is no way to put "old method" statistics for this LRU together with "old method" statistics on other LRUs to get an overall support burden "big picture." MMUT overcomes this problem. Observe in Table 8 that the required support burden for one operational LRU hour is .130 maintenance man-hours. This is distributed to each maintenance level as .059 o-lvl man-hours, .060 i-lvl man-hours, and .011 d-lvl man-hours. These MMUTs can be simply summed to other LRU MMUTs at every maintenance level (Table 4), giving every manager at all maintenance levels meaningful "big picture" support burden statistics.

MMUT is a direct measure of R&M 2000 goal number four. The man-hour requirements of *any* system at *any* maintenance level are clearly and accurately displayed by the MMUT statistic. The statistic offers another advantage: it facilitates a means to obtain R&M 2000 goal number four; that is, it facilitates a maintenance optimization scheme.

Maintainability Optimization Scheme

Central to any maintainability optimization scheme is a maintainability statistic that can be extended to all maintenance levels and across all repairable items. This is the primary advantage MMUT has over other statistics. Mean time per unit time (MTUT) is another new statistic and is identical to MMUT except MTUT uses time to repair where MMUT uses man-hours to repair. MTUT has the same advantages over other statistics as MMUT. In addition, MTUT will facilitate the optimization scheme for manpower allocation.

The question is: "How can maintenance resources be best allocated to maintain a system?" MTUT is dependent upon the physical configuration of the system, the troubleshooting process, the manpower available, and the skill levels of the maintainers. Within certain limits, the maintenance manager can change each or all of these factors, thereby influencing MTUT and consequently altering system supportability. Given limited resources, such as total maintenance man-hours available for the average skill level, how should the maintenance manager allocate these man-hours?

Before delving into the optimization scheme, it is necessary to understand what will be referred to as *failure mode*. Any given repairable item may fail in a variety of ways. A given failure may require repair at just the o-lvl, or it may require being passed on to i-lvl or even d-lvl maintenance. A *failure mode* of a given repairable item is simply a distinct way in which it fails requiring a distinct method of repair. The example in Table 9 will clarify this.

	Repair Level		
	o-lvl	i-lvl	d-lvl
Repairable Item #1	Failure Mode 1 Failure Mode 2 Failure Mode 3 Failure Mode 4	Failure Mode 1 Failure Mode 4	Failure Mode 1 Failure Mode 3

Table 9.

In Table 9, repairable item #1 has been determined to fail in one of four ways. Failure Mode 1 requires repair action at all three levels of maintenance, Failure Mode 2 requires only o-lvl maintenance, Failure Mode 3 requires o-lvl and d-lvl maintenance, and Failure Mode 4 requires o-lvl and i-lvl maintenance. I chose this example because it covers every possibility for a given failure mode. As can be seen, all failure modes require action at the o-lvl, where the failure is recognized and some action must be taken. This would not have been recognized if man-hours were allocated under the "old method." Under the "old method" for allocating man-hours, a repairable item could have been removed and replaced with no man-hours attributed against it. The man-hours would have been lost in that ambiguous "system maintenance" category. Under the "new method," MMUT requires man-hours (and MTUT requires hours) be attributed to the failure causing repairable item and eliminates the "system maintenance" category. In addition to allowing summing across maintenance levels and repairable items, accurate man-hour accounting is another reason why MTUT is used in this optimization scheme rather than other maintenance statistics. Getting back to the example in Table 9, the four failure mode possibilities do not preclude an item from having

more or less than four failure modes. For example, a given item could have multiple failure modes requiring o-lvl and i-lvl maintenance, and no failure modes requiring o-lvl and d-lvl maintenance. However, the definition of *failure mode* explained in this paragraph will be assumed through the remainder of this paper.

Within the supportability optimization scheme, we do not consider the fact that field MTTR is variable depending on the size and skill levels of the maintenance team. Our assumption is that the data base will be large enough to drive these variable considerations to a norm. We further assume fixed failure rates and manipulate repair rates. Inherent failure rates are often beyond the control of maintenance personnel but repair rates are not. So the process of maintainability allocation depends on knowing the failure rates for each mode and manipulating the repair rates for each mode. Failure rates come from two sources: data or predictions. If the system is in the field, failure rates calculated from collected data are most reliable. This may not be possible if the system is still in the design phase. In this case failure rates for repairable items would be the natural product of an R&M prediction in accordance with Military Handbook 217. More complicated optimization schemes with fewer assumptions are planned for the future, given the success of this scheme.

The next step is to determine the repair capability of each maintenance level for each failure mode. This capability is reflected by minimum and maximum repair rates for each failure mode. Minimum repair rate would be a constraint placed on each failure mode due to required availability considerations. Maximum repair rate would be a constraint placed on each failure mode by the manpower available at that maintenance level. For example, for a given repairable item, availability considerations may require certain maintenance personnel to meet a minimum repair rate of 10 repairs per hour. On the other hand, for this same repairable item, the maximum repair rate due to manpower limitations in the maintenance shop might be 20 repairs per hour. Maintenance managers must set their repair rate target for this repairable item between 10 and 20 repairs per hour. Maintenance managers cannot simply target the maximum repair rate; because with a fixed resource of available man-hours, they would automatically divert resources away from other repairable items. So given many repairable items with several different failure modes each, and given the min - max repair rate constraints on each item, how should maintenance managers choose to target repair rates for each item in order to optimize manpower utilization?

That is exactly the question this optimization scheme answers! Given MTUTs (failure rates divided by repair rates) for each failure mode and fixed manpower available, the optimization scheme will optimize repair rates over all levels of maintenance. Remember, to simply minimize MTUT by maximizing repair rates does not take into consideration the condition of fixed manpower. To maximize the repair rate on one item necessarily prohibits maximization of another item's repair rate. The problem statement requires consideration of this trade-off. For this reason a penalty function is part of the problem statement. Because slight improvements in repair rates are often easier than large ones, the summation of the squares is an intuitively appealing penalty function. With this choice of a penalty function, large improvements in repair rates will be prohibited. So the problem statement is as follows:

$$\text{Minimize} \quad \left[\text{MTUT} + \sum_{i=1}^{n} (\text{repair rate}_i) \right]$$

or in other words,

$$\text{Minimize} \quad \left[\frac{\text{failure rate}}{\text{repair rate}} + \sum_{i=1}^{n} (\text{repair rate}_i) \right]$$

Note that increasing repair rates will lower the MTUT term but at an expense of increasing the penalty function (sum of squares term). To minimize the support burden given the manpower limitations, maintenance managers can optimize their choice of target repair rates for all repairable items by minimizing (MTUT + appropriate penalty function).

After the problem formulation described, all that remains is to solve the optimization problem using a suitable mathematical technique. Because the decision variable (repair rate) is in the denominator, and a quadratic penalty function exists, a nonlinear optimization technique is suitable. While there are a number of optimization techniques available, the ellipsoidal algorithm was chosen for this application. This algorithm was chosen for reasons of convenience, accessibility, and ease of implementation on a microcomputer. For larger systems, with hundreds of repairable items and subsequent failure modes, other techniques may be more suitable. The technicalities of this mathematical approach are not warranted in this discussion; the best way to demonstrate the worth of this optimization scheme is by example.

Suppose a simple system is composed of two repairable items where each repairable item has three failure modes. Also assume the system demonstrates the characteristics listed in Table 10. Failure rates in Table 10 are failures per operating hour and repair rates are repairs per hour (the items are obviously quite simple to repair in this case). The Current System MTUT at each level is simply the sum of failure rates divided by their respective repair rates at each level.

			Maintenance Level		
			o-lvl	i-lvl	d-lvl
Repairable Item #1	Failure Rates	Failure Mode 1	.010		
		Failure Mode 2	.005		
		Failure Mode 3	.001	.001	
	Current Repair Rates	Failure Mode 1	10.0		
		Failure Mode 2	5.0		
		Failure Mode 3	2.0	5.0	
	Maximum Repair Rates	Failure Mode 1	20.0		
		Failure Mode 2	10.0		
		Failure Mode 3	10.0	10.0	
Repairable Item #2	Failure Rates	Failure Mode 1	.050		
		Failure Mode 2	.001	.001	.001
		Failure Mode 3	.001	.001	.001
	Current Repair Rates	Failure Mode 1	15.0		
		Failure Mode 2	5.0	10.0	1.0
		Failure Mode 3	3.0	10.0	1.0
	Maximum Repair Rates	Failure Mode 1	25.0		
		Failure Mode 2	10.0	20.0	3.0
		Failure Mode 3	8.0	20.0	3.0
		Current MTUT:	.0064	.0006	.0020

Table 10.

If the o-lvl managers were just given an increase in manpower of 22%, they would no doubt expect a corresponding 22% improvement in their MTUT; that is, their MTUT should drop to below .0050. Which failure modes should they add the manpower to in order to increase repair rates thereby attaining this .0050 MTUT? The optimization scheme was run with the following constraints:

(1) Current Repair Rates are minimums.
(2) Maximum Repair Rates as given.
(3) MTUT less than or equal to .0050.

The results of the optimization are listed in Table 11.

			o-lvl Maintenance
Repairable Item #1	Failure Rates	Failure Mode 1	.010
		Failure Mode 2	.005
		Failure Mode 3	.001
	Target Repair Rates	Failure Mode 1	10.4
		Failure Mode 2	8.2
		Failure Mode 3	4.8
Repairable Item #2	Failure Rates	Failure Mode 1	.050
		Failure Mode 2	.001
		Failure Mode 3	.001
	Target Repair Rates	Failure Mode 1	17.8
		Failure Mode 2	5.0
		Failure Mode 3	4.8
		Projected MTUT:	.0050

Table 11.

This shows maintenance managers how to optimize their added resources. This is merely an isolated example. This optimization scheme can also be used to optimize current manpower utilization or optimize utilization of manpower resources which are altered due to a change in maintenance concept (such as the elimination of intermediate level maintenance).

Conclusion

MMUT is a simple indicator of R&M 2000 goal number four, and MMUT's "cousin" MTUT facilitates the means to attain the goal. These simple statistics will allow maintainers to optimize manpower requirements per unit of output required to achieve warfighting availability goals. In this advanced technological environment, maintenance support (or MANPOWER) is a critical resource. In the event of a next war, it will not be won by superior technology; rather, it will be won by a country's ability to *optimally* support and maintain that superior technology.

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Continued From Page 10

cooperation initiatives will require a change in our approach to doing business. We will need to increase our awareness of the political and economic environment which exists in the weapon acquisition of ourselves and our allies. The "Buy American" mentality will have to yield to a different mindset which permits the search for the best weapon technologies and the development of them in such a fashion to maximize our military advantage with the minimum expenditure of resources. In the short term, the logistician may be burdened by the proliferation of new considerations which must be made in the international acquisition environment. This will be balanced, however, by long-term gains in available resources and improved supportability. If, as Under Secretary of Defense James Wade has said, our emphasis must be on defense, not defense commerce, then international cooperation needs serious consideration, and the logistician must be in the vanguard of those seeking an improved defense posture.[25]

Notes

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Using Enemy Air Bases to Support the Counteroffensive: A Support Perspective

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In a counteroffensive, how can we maintain air bases relatively close to the front lines to minimize reaction and flying times for fighter/bomber support of the land battle? This paper will discuss the crucial elements to reconnoiter, seize, clear, repair, or construct an air base in former enemy territory.

Background

Air forces have had a lot of experience following armies into recently conquered territory and setting up air bases from which to fly and fight. Early in World War II, engineer officers in the Army devised the self-contained aviation engineer battalion. It was capable of constructing a complete advanced airdrome because it was sufficiently equipped: 220 items for construction, including 146 vehicles—diesel tractors with bulldozers, carryall scrappers, graders, gasoline-powered shovels, rollers, mixers, air compressors, drills, trucks, trailers, asphalting and concreting equipment, rock crushers, draglines, and pumps. (24:240) The Japanese, on the other hand, were trying to build airfields with much less equipment in their engineer battalions. (19:444)

Even with lavish stateside preparations, things did not always go smoothly for our engineers. In the early fighting in North Africa during Operation Torch, the unloading of the 21st Engineer Aviation Regiment's equipment had been marked by confusion—an experience which carried an obvious lesson concerning the need for more systematic loading in later invasions. Fortunately, the regiment moved into two captured French airfields with little to do except fill in some bomb craters. (24:248-251) As they gained experience, the engineers could receive a request and provide five fields for fighters within 72 hours. (24:251)

Early deployments during that war were very different from those we would mount today. During Operation Torch, Twelfth Air Force was partly flown in from Gibraltar and partly from escort carriers directly from the States, but was *largely* brought in by ship for reconstitution before operations began. A critical factor that severely limited both aircraft and maintenance capability was the need to ship in large numbers of trucks for movement from one airfield to the next as the front lines shifted forward. C-47s of the Air Transport Service were also used extensively to move supplies, parts, mechanics, etc., to keep the offensive momentum going and to fill quick-reaction needs. (23:72, 82, 84)

The Army Air Forces built on the early experiences in North Africa to move into Sicily, Italy, and France with ever-increasing effectiveness as the land battle moved closer to Germany. Engineers honed the requirements needed at each new base and established flexible checklists for equipment and supplies—those needed immediately, those that could wait, and those not needed at all.

Today, we are not as dependent on ships as during World War II. Now, with air refueling and the long legs of transport aircraft, we can deploy directly from the Continental United States (CONUS) into an objective area and set up immediate operations on a bare base. A bare base is defined in our mobility doctrine as a runway (taxiway, parking apron) and a source of water. (30:A1-1-1-2) It presumes the US is invited into an area, and the runway is intact and the water not contaminated beyond recovery.

The US Air Force has long been tied to fixed bases. Although we practice mobility and can move several squadrons and their support to another bare base, we are still tied to a base. Our aircraft have become so complex that support in essence requires operating from a fixed location, with hard runways and preferably taxiways and hangars. In the 1967 Middle East war, the Egyptian Air Force was destroyed on the ground by Israelis coming in low, at Egyptian shift change, and with almost complete surprise. Since then we have engaged in a gigantic, worldwide aircraft shelter-building program designed to ensure "it won't happen here."

We discovered in the Philippines (1941-1942) and in North Africa (1942-1943) how difficult it is for ground forces to operate effectively when the enemy rules the skies. To provide the air cover needed to ensure victory, we need to regain the flexibility to establish forward air bases quickly in enemy territory. (33:8-4,5)

The problem discussed presumes there are no bare bases on which to set up. Instead, we must go into the territory occupied by enemy forces after they have done their best to destroy anything we might find useful.

The Concept

For several years, we have planned on how to fight outnumbered and win. This boils down to forward defense (the West Germans and the South Koreans do not want Communist forces occupying large tracts of their territory), identifying the major enemy thrusts and bringing overwhelming firepower to bear on those thrusts with the forces in line and directly in support of the forward line of troops (FLOT). We then identify enemy follow-on forces before they can join in the main battle, destroying those forces largely through the use of air power and stabilizing the situation with minimal loss of territory. Finally, we strike concentric blows in a counteroffensive to destroy the enemy forces enmeshed in our defenses and push deep into their territory to make them pay dearly for their aggression. (3:222, 236, 237; 33:8-2)

While we are engaged in defensive operations, we must prepare for the counterstroke and gather resources needed to ensure its overwhelming success. There will be little time to plan ahead. Therefore, we must think through the problems of

counteroffensive now. The Air Force part in the battle will include tasks we practice daily, such as offensive and defensive counterair, close air support, interdiction, perhaps some strategic bombing, tactical airlift, reconnaissance, and close cooperation with the ground forces through air liaison officers. Our requirement will also include tasks we have not practiced since Korea and which have not been thoroughly tested since World War II. How do we establish airfields in former enemy territory so that fighter/bomber operations against the enemy are maximized and flying time to and from the objective area is minimized?

Conditions at the Front

As enemy forces retreat, they will destroy culverts, bridges, dikes, dams, and buildings. (6:167) They will also destroy crops, food stocks, railroad tracks, and signaling equipment. Telephone lines and switchboards will be rendered unusable; water will be contaminated and animals driven off or slaughtered. In short, we still face slow going with little help from a possibly hostile population. The job of cleaning up and preventing the spread of disease will be burdensome. (35:33)

One major point should be made about road movement in the presence of large numbers of tracked vehicles such as tanks. No matter how strongly existing roads are constructed, when large numbers of 50-ton vehicles traverse them, the surface will break up. The more traffic, the faster the breakup. Roads leading to the front lines behind our counteroffensive will have been heavily traveled by earlier enemy attacks upon our forces, then subjected to an equal pounding as we push into the enemy's rear areas. Artillery and bombing will also take their toll on the road network. Engineers will have a tough time repairing these roads while they are being used, and the materials they initially must use will be expedient substitutes for the reinforced concrete that could hold up better under wartime conditions. As seasonal rain or snow begins, these roads will become passable only to tracked vehicles, of which we have very few devoted to the resupply mission. Consequently, as the front advances and our own sources of supply are left farther behind, road traffic can be expected to increase, more vehicles will be required to keep the same level of supplies going forward, and the roads will deteriorate ever faster. (6:165,37) The result is that airlift increasingly will be required to maintain resupply to the forward most ground units, and less lift will be available for moving Air Force cargo. (15:81, 9:145)

Enemy air bases will surely get the same destructive attention as the rest of the infrastructure. Unexploded ordnance, both ours and theirs, will threaten our operations; runways and taxiways will have sustained major damage from our attention and theirs; booby traps will be plentiful in or around anything that looks remotely usable; and enemy troops or partisans will infest some areas to slow down our counter-offensive. (6:385;6:167)

Locating a Suitable Base

The enemy's own offensive has been stopped and we are holding them on the ground. Our air forces are pounding the enemy forces' second echelon and rendering it ineffective to reinforce any momentum they may gain. Our ground and air forces are ready to give the enemy forces a taste of what they did to us in the first weeks of war. Our deployments to the theater are complete, lines of resupply are established, and frontline stocks are sufficient to take the battle to the enemy. (33)

In our effort to support the ground forces, we must move some of our short-range aircraft closer to the front lines to provide a base for recovery, quick-turn, and short distance to targets, and allow for increased loiter time or increased bomb loads. Consider for a moment the type of facility for which we ought to look:

(1) We should search for an enemy air base that is 100-200 miles forward of our existing base nearest to the front lines. If possible, it should be out of the enemy's artillery range (approximately 30-40 miles behind the FLOT) (18:84-97, 1:49-57), in an area where the Army can assure the absence of any major enemy concentrations, and situated so we can have a reasonable amount of warning time in case of enemy air attack.

(2) We should analyze intelligence reports to find out where their fighters, bombers, reconnaissance, and transport aircraft are based. Their fighter and bomber bases must be hit especially hard by our own forces, but it might be possible to attack their transport or reconnaissance bases less heavily and thus preserve them for our own use. For example, fighters will be revetted and thus hard to target; consequently, we would have to concentrate on runway and taxiway systems to keep enemy fighters on the ground. But transports are too big to revet and presumably could be attacked using 20- or 30-mm fire or other weapons that would destroy the aircraft, but leave the airfield infrastructure relatively intact. If the enemy bases aircraft by type (fighters at one base, transports at another, or at least largely so), then a strategy as described could be successful. However, if enemy bases aircraft by strike packages, this may not work.

If potential bases are identified, the air component commander must influence the ground component commander to include these bases in the objectives of the counteroffensive. In addition to progress reports from ground forces, the Tactical Air Control Party (TACP) should keep the Air Support Operations Center (ASOC) informed of the offensive's progress and provide initial ground reconnaissance of the objective air base(s). (33:8-5)

Initial Requirements

Early in the conflict, we must begin to assemble those things which might be needed for reopening a captured air base (personnel, equipment, supplies), and the means for getting them forward. As a starting point, I suggest including the following capabilities:

- A Combat Control Team (CCT) to be first in to assist in determining when the airfield is ready to receive aircraft and to control aircraft during initial operations. (22:57)
- A security police team equipped with stinger anti-aircraft weapons to secure the base perimeter for the repair teams.
- A Prime BEEF damage assessment team to survey the air base and determine what additional facilities, materials, and equipment are needed to make it operational.
- Communications capability.
- An explosive ordnance disposal (EOD) team to help identify and dispose of unexploded munitions and booby traps.
- A medical team for military personnel and civilians. Medics must verify usability of water supply and the spread of disease that would accompany the destroyed infrastructure and burial of the dead left behind by ground fighting or air attack.

Movement to the Captured Airfield

In most cases, our ground transport organizations are combined with the host nation or under alliance supervision. For example, in Korea we operate under a Combined Transportation Movement Center (CTMC), which has all movement (ground—rail or road—air, water) under its jurisdiction. The CTMC controls everything back of the division commander's area (approximately 30 miles from the FLOT, although this could vary depending on terrain and other factors).

The Army, especially the division or corps commander in contact with the enemy, controls transportation lines into and through the battle area and back a considerable distance from the front. This control must exist because of engineers repairing the roads in the rear areas, the flow of supplies to the forward-engaged ground units, the retrograde movement of casualties and damaged equipment, or prisoners. The commander may or may not be able to block space and time on the road network to accommodate the Air Force. The air component commander must be kept fully informed so he can represent our transportation requirements for both the initial assessment and refurbishment teams to the ground commander. (3b)

It may be necessary to move initial teams onto the air base by heavy lift helicopter. If so, the Air Force may have to rely on the Army commander to make CH-47s, or a similar capability available. Depending on Army requirements, we may not receive adequate support.

A third possible way to move to the objective area is by tactical airlift in an airland mode. This would require a minimum clear zone of 2700 feet, 100 feet wide on or close to the air base. (21:78) Although equipment could be rigged for the airdrop or low-altitude parachute extraction system (LAPES), our engineers and other support personnel are generally not parachute qualified. This is an expensive and not-too-efficient method to insert units, and it would be far better to get the entire unit there by road.

Lightly Damaged Airfields

If initial reconnaissance shows little damage, booby traps, or threats, we may be able to bring in a small team to get the base ready for our aircraft. This situation could develop particularly if the Army put paratroops or airlanded units onto the base ahead of the main offensive to secure it for our use. Also, the counteroffensive could develop so rapidly that our ground units take the base on the run before the enemy could damage or booby trap it to any great extent. (33:4-6) Airfields which the enemy has abandoned in a hurry to avoid our advancing spearheads would be particularly suitable, since there would be less opportunity for extensive sabotage or booby traps.

Additional Requirements for Heavily Damaged Airfields

It is more likely, however, that the enemy would gain knowledge of our advance toward any specific air base and destroy or damage as much as possible. If this situation occurs, we would need much heavier units than under the previously discussed circumstance. In addition to the six initial capabilities, we would need the following, depending on results of reconnaissance:

- Additional Prime Beef or Red Horse personnel and equipment.
- A vehicle maintenance capability.
- An aerial port capability to receive and ship equipment, supplies, and personnel by air.
- R-14 fuel bladder system and personnel.
- Munitions teams.
- A military government capability.

It is unlikely that we would have sufficient manpower to accomplish all the tasks quickly. However, we may be able to employ local labor for some of the less critical jobs (digging, chalking) in return for food.

Soviet and their Allies' Airfields

The Soviets have perfected a type of rapid construction of airfields that is truly impressive. They build steel-reinforced concrete sections approximately three meters (10 feet) square under controlled conditions, thus ensuring uniform quality. These are then shipped to where an airfield is desired. Meanwhile, engineers or construction workers have prepared a site for the base, tamping the earth, laying gravel, and arranging drainage. When the concrete sections arrive, they are lifted into place by cranes and an airfield is ready for operations in short order. The Soviets maintain a supply of these sections near their airfields to repair bomb damage quickly. (38)

Soviet-style airfields are characterized by an uneven surface when compared to US runways—it would be sort of like the clickety-click of a train on a track as an airplane taxis or lands on such a strip. This is tough on landing gear, but Soviet fighters are built to operate in such conditions. The more modern US fighters are not, although C-130s, OV-10s, A10s, and F-4s could stand the beating for varying lengths of time. F-15s and F-16s would only be able to use former Soviet runways for in-flight emergencies or in the most dire of circumstances. (39)

The Operation

We have identified a former enemy transport base about 200 miles from our most advanced base in friendly territory. The Army forces have passed through this area and are about 50 miles beyond the identified base. Our TACP has given us a preliminary report on the damage they can identify.

We now send five helicopters laden with our advance team, consisting of security police, EOD, a Prime Beef damage assessment team, CCT, some communicators, and a small command element. The security police are in first, followed closely by the EOD personnel. They fan out to secure the landing site, and the EOD team starts marking explosives for later demolition. These markings must be clear and conspicuous, allowing others to avoid them. The command element and communicators, together with the CCT, set up a command post and establish links with the main base and others, such as the air component command headquarters and Airlift Control Element (ALCE). The Prime Beef team and CCT begin EOR and damage assessment as well as cataloging materials already available on the base to aid in reconstruction.

The team has arrived at first light, and the preliminary report goes back to base by noon, with a follow-up at dusk. Based on the noon report, a convoy forms during the afternoon and early

evening, convoy clearances are obtained from the Army division commander, and the first units move out before midnight. These consist of additional security police for protection en route and to beef up security in the objective area, and Prime Beef or Red Horse personnel and their equipment, including a small dozer, a 25-ton crane, several dump trucks, M-35 2½-ton trucks, a P-19 fire truck, and more. Also included are additional EOD personnel with specialized vehicles and equipment to clear the airfield, a vehicle maintenance capability, and a small medical/public health team to begin cleanup and normal operations. In the next few days, added capabilities arrive, mostly by convoy, some by air: a combat control team for getting airlift in and out; a military government team to organize the local populace and put them to work; an additional R-14 refueling system and the personnel to run it; and other support such as supply, food service, and traffic management personnel. Also, additional heavy equipment arrives and is immediately put to work.

The unit was fortunate in finding a stock of the concrete sections for runway repair left behind by the retreating enemy, for they make the job go much faster. If these were unavailable, we would need stocks of polymer concrete or polyurethane fiberglass mats. Bundles of AM-2 or AM-19 aluminum matting are used to establish dispersed parking areas and access taxiways (37, 38).

Work progresses rapidly, and within 48 hours the first OV-10 lands on the 1500 feet of runway cleared to that point. Within 72 hours, C-130s can operate in and out, with over 5000 feet available. Within five days, the airfield should be able to handle all tactical aircraft in the combat area.

Conclusion

This paper has briefly considered what must be done to occupy and use enemy airfields for our own air operations. Preparations should start during our defensive and buildup phases when we identify potential airfields that we might use, and coordinate with the ground forces to see which are most feasible from their point of view. Next, we gather the specialized teams needed to secure and repair the air base, and arrange transportation to their destination. During the counteroffensive, our assessment team deploys to determine how much of each capability we need to make the field operational. Based on the on-site assessment, necessary personnel, equipment, and supplies are rushed to the captured base to complete the reconstruction process. Finally, after their work is complete, the teams reassemble for the move forward to their next assignment.

Today, in this changing world, the U.S. military could instantly be plunged into another conflict—in Europe or elsewhere. As a part of our planning, the Air Force must examine its ability to occupy enemy airfields in order to enhance our chances for victory. The Air Force must be capable of supporting early sortie generation with organic forces. Beyond this, we will need support from Army Engineers if we are to have a fully functional air base.

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"Strategy, like politics, is said to be the art of the possible; but surely what is possible is determined not merely by numerical strengths, doctrine, intelligence, arms and tactics, but, in the first place, by the hardest facts of all: those concerning requirements, supplies available and expected, organization and administration, transportation and arteries of communication."

Supplying War by Martin Van Creveld

First Flight of the American Aircraft Industry: Factors Influencing Expansion (1939-1940) and Results

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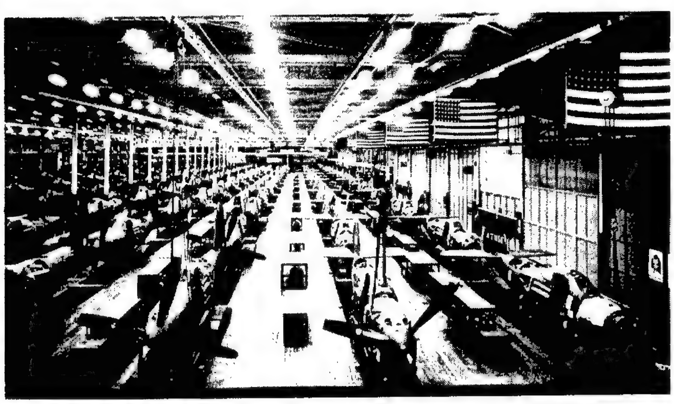
Introduction

For the first time in military history, aviation played a significant role in determining the outcome of World War II. For government and industry involved in the production of war materials, maturing of large-scale aircraft production was the most dramatic development of the time. Large shipbuilding operations were not new and mass production of ordnance items was well established, but the manufacture of aircraft in mass production quantities had never been attempted in the United States. The early uncontested victories of the Luftwaffe forced the allies to call upon American industry to produce large numbers of military aircraft in a very short time. Despite the acknowledged need for aircraft, the United States was neither willing nor able to produce those aircraft prior to 1940. This relatively late surge in aircraft production had near tragic consequences.

The story of the industrial birth of the global air forces that won the allied victories is nothing short of amazing. By V-J Day, and in just over five years, the aircraft industry grew from a skeleton existence, barely surviving, to produce over 300,000 military aircraft for the Army, Navy, and allies. The Army Air Forces accepted 158,880 aircraft, including 51,221 bombers and 47,050 fighters. By war's end, the annual production rate was almost 100,000 aircraft. (1) This herculean effort by government and industry is even more astonishing because production of these aircraft was, in large part, accomplished within the American free-enterprise system where profit and loss was still a bottom line.

Setting the Stage

Despite its industrial potential, America had done little since the end of World War I to improve its overall military might and potential for waging war. Because of a political



Assembly Line for Bell P-63 "Kingcobra."

climate which was influenced by powerful isolationist groups, the US was not greatly concerned with issues beyond its boundaries. In the more than eight months between the German attacks on Poland and France, the United States took no decisive steps to rearm. In fact, as late as April 1940, the House of Representatives was ready to reduce the War Department's request for obligated funds by 9.5% for fiscal year 1941. (2)

Although some military and civil leaders foresaw US involvement in the unfolding world crises as inevitable, most attempts to prepare for war in Europe were met with stiff civilian resistance. Basic philosophy and objectives guiding prewar mobilization hindered, rather than stimulated, preparation for war. New attempts to develop plans for industrial mobilization were rejected, and Congress failed to support the existing Industrial Mobilization Plan. (3) Mobilization plans at that time were based on the premise that "the next war, if there should be one, would be on a smaller scale than the last one." (4) For business and industry, an established rule of industrial planning in case of war was that one-half of the normal capacity of any factory with a civilian market would be reserved for civilian production. (5) The idea of a global world war was simply not contemplated.

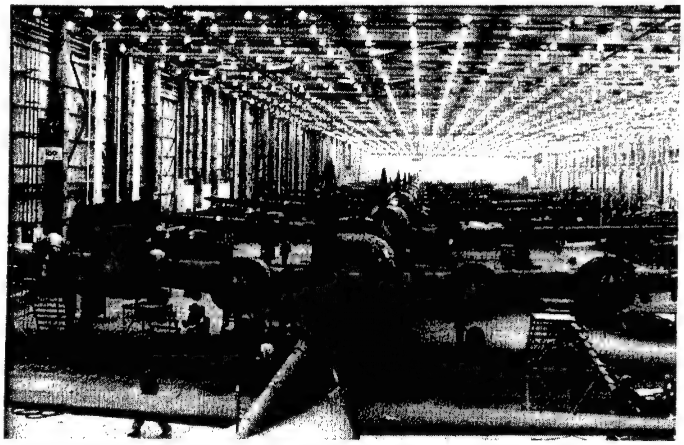
The Prewar Aircraft Industry

Thus, as constituted in 1939, the US aircraft industry did not have the capacity to produce the planes foreign nations and our military wanted and would need for the war effort to come. The industry was pretty well concentrated in a handful of companies which had survived the depression; more well-known among them were the aircraft builders, Lockheed, North American, Boeing, Martin, Consolidated, and Curtiss. Several of the engine manufacturers and smaller contractors to later take part in the expansion of their facilities included Wright Aeronautical Corporation, Bell, Vultee, Fairchild, Brewster, and Pratt & Whitney. (6) These contractors had been kept alive only by virtue of government contracts for military planes, and that source of business was too erratic to encourage plant expansion or the adoption of mass production techniques.

Once the tide of Nazi aggression began to engulf western Europe, allied leaders began to recognize the need for a large and rapid expansion of the armed forces. Critical to this expansion was the Air Corps. The small size and the technically complicated character of the Air Corps and its equipment presented a more difficult challenge for expansion than did any other branch of service.

As sentiment changed concerning the inevitability of US involvement in the war, both industry and government

acknowledged that rapid expansion was necessary. Four alternatives were considered: (1) government factories; (2) an increase in plant capacity by the aircraft industry itself; (3) more subcontracting by the major companies to smaller aircraft firms and organizations outside the industry; and (4) conversion of other industries, especially the automotive, to aircraft production. Of these methods, only the second was acceptable to the large aircraft manufacturers. Recalling unpleasant memories of overexpansion in World War I, they were anxious for facility expansion to be provided by the government, without cost to themselves. (7) No businessman wanted to make a large capital investment in expensive plants that would have to be sold cheaply during a postwar depression. Business leaders made it clear that if the government wanted aircraft, the government must assume a hefty share of the risks inherent in large and rapid growth.



Boeing B-17 Final Assembly, Douglas Aircraft Co., Long Beach, California.

Allies Need Aircraft

As early as March 1938, evaluations of the capability of US industry were underway. The British, anticipating the outbreak of hostilities with Nazi Germany, and having authorized the expansion of their own aircraft industry, dispatched an air mission to North America to determine if its industry could produce a portion of the needed aircraft. Among the members of that mission was Air Commodore A. T. Harris, later the famous "Bomber" Harris of R.A.F. Bomber Command. (8)

The mission found American aircraft industry operating in skeleton fashion and barely able to keep up with the thin stream of incoming orders. The US armed forces were limited by statute to an air force of 2,300 planes, and the Navy to one of 1,000 planes. In the year ending 30 June 1938, the Army and Navy had appropriations to buy a total of only 900 planes.

After visiting almost all the large companies, the British mission placed only two small orders; however, both had important consequences. The first, with North American Aviation for advanced trainers, was the beginning of a long series of British orders for thousands of trainers. They were called "Harvards" by the British and they trained thousands of RAF fliers under the Commonwealth Training Program. The other order, for long-range reconnaissance bombers, gave birth to the famous Lockheed-Hudson bomber, of which the British bought more than 1,300. (9)

About the same time the first British mission came to the US, the French placed their first plane order in this country. It was for 100 Curtiss-Wright P-36 fighters, the predecessor of the famous P-40. These two early purchases by Britain and France were just the beginning of a wave of aircraft orders. By mid-1940, British and French orders were for a remarkable quantity—over 8,000 planes and 13,000 engines. This brought the total French and British aircraft orders placed in the United States in the 18 months between 1 January 1939 and 30 June 1940 to 10,400. In the same period, our own Army and Navy had increased their orders to 4,500 aircraft. (10)

The Production Goal

As France and Great Britain placed increasingly large aircraft orders with US firms and our armed forces began their expansionary phase, President Roosevelt, on 16 May 1940, announced to a surprised nation a plan calling for the production of 50,000 military aircraft per year. (11) To the "business-as-usual" nation, the President's request was a sudden shock. Under production schedules previously developed for future years, the maximum number of aircraft to be produced in any one year was 29,500, and the peak monthly rate under those schedules barely exceeded 3,000 aircraft. (12) Other statistics show the immense proportions of this request. The aircraft industry was tasked to expand from its existing normal capacity of some 2,000 planes a year to more than 4,000 per month. Aircraft production in 1940 was to show an increase of 250% over the previous year. (13)

President Roosevelt's tendency to state objectives in huge round figures was meant to have an energizing effect on public opinion, but such objectives had to be translated into more precise military terms and production schedules. Twelve days after the President's announcement, the first major step was taken toward creating a government organization capable of assuming responsibility for such a huge national defense production program. The President's plan called for the formation of a seven-man National Defense Advisory Commission (NDAC), placing it under the control of Mr. William S. Knudsen, then president of General Motors. Mr. Knudsen was to be Commissioner of Industrial Production and the aeronautical section under him was charged with the responsibility of managing the aircraft production program. (14) The aeronautical arm of the National Defense Advisory Commission (later to become the Office of Production Management) represented the beginning of the close relationship government and industry needed to accelerate aircraft production.

As alluded to earlier, probably the single most important stimulus to the early expansion of the American aircraft industry was English and French demand for its products. It is also likely that the expansion, financed by British and French funds in 1939 and 1940, advanced by as much as a year the time in which American aircraft production would reach its peak. As Secretary of War Stimson later said in a February 1941 letter to Senator George while the Lend-Lease Act was being debated:

> Bearing in mind that it takes from 18 months to two years to develop production of a new aircraft motor and about 16 to 18 months to develop production of a new model airplane, you will realize that without the head start given industry by these foreign orders we would at the present time be in a very grave situation . . . . (15)

By September 1940, the British had ordered more than 14,000 aircraft. Engine orders totaled 25,000 with options for 28,000 more. The value of these contracts, about $1.5 billion, represented half of the dollar-volume of the all British

munitions contracts. (16) The Anglo-French engine program alone involved a total capital outlay of $84 million but did not include any engines. Rather, it created new capacity to make engines. This was of vital importance if we were to reach our 50,000 aircraft per year goal. (17)

However, by the close of 1940, the British were near the end of their ability to pay for munitions in the US. Allied investment already totaled over $200 million. And because of the Johnson Act of 1934, which prohibited credits to nations that defaulted on World War I obligations to the US, there was no way for them to secure needed credit. At this critical point, President Roosevelt called upon the nation to be the "arsenal of democracy" and the Lend-Lease Act of 11 March 1941 was passed authorizing the transfer of weapons and equipment to countries whose defense was considered in the interests of the United States. Existing allied contracts remained intact and deliveries were made into 1944. (18)

Capacity Expansion

All of the larger and some smaller aircraft companies participated in the industrial expansion, which had begun to assume boom proportions by the spring of 1940. Boeing, Lockheed, Douglas, Martin, Consolidated, North American, and Curtiss—the large airframe makers—greatly expanded their capacity during this period. Lockheed, an early recipient of large British orders, more than doubled its manufacturing floor space. Smaller firms like Bell, Vultee, Fairchild, and Brewster also added new space. Both Wright Aeronautical and Pratt & Whitney enlarged their engine plants, the latter quadrupling capacity between May 1938 and May 1940. The aeronautical industry spent more than $52 million for plant expansion and new equipment between 8 September 1939 and July 1940. Of this, more than $34 million went into engine and propeller plants and $13 million into airframe plants. (19) Floor space in airframe, engine, and propeller plants increased. (20)

One of the main reasons American capacity was able to expand so rapidly lay with the willingness of the government to use resources outside the aircraft industry itself. Interestingly, the main subcontractor for aircraft production, particularly for engines, was the automobile industry. This was possible not because of any basic similarity of product, but because the auto industry had the necessary installations, skilled workers, and a large supply of tools available for conversion to wartime use. In October 1940 Mr. Knudsen compelled automakers to enter into negotiations with the aircraft industry over war mobilization. The result was the Automotive Committee for Air Defense. This committee developed conversion plans and negotiated with the government on contractual and financial matters. The Automotive Committee insisted that new facilities be provided and paid for by the government. Some 66% of auto industry tooling in 1942 was used in the aircraft industry. (21) In total, the auto industry produced over 50% of all aircraft engines and 40% of all airframe production by weight.

Production Planning, Boeing Aircraft Company.

Without help from the auto industry, aircraft producers would have been unable to cope with the scale of contracts after 1941. Other sectors of industry, notably appliance and electrical parts manufacturers, were also drafted into the aircraft program as subcontractors, including significant contributions from the electrical giants General Electric and Westinghouse. (22)

Domestic Financing

In the early months of mobilization, primary reliance was placed upon privately financed expansion. A few companies commenced expansion prior to obtaining firm contracts, but others hesitated to take the risk. Many nonaircraft firms, particularly in the auto industry, refused to take war orders in 1940 and 1941 unless the government provided all funds for expansion, or unless all other firms in their particular sector were also compelled to take war contracts. Such reluctance was fed by the fact that firms were experiencing a boom in consumer orders for the first time since the Great Depression and were not willing to sacrifice potential profits. The critical factor for most firms was that they simply did not have the resources needed to finance large-scale expansion for the war effort. Uncertainty prevailed until the conditions of financing could be arranged.

For industry, government financing to reduce risks associated with wartime expansion was essential and one of the first examples of major government intervention in the aircraft industry. The first step was creation of the Reconstruction Finance Corporation (RFC) to make loans to, or buy capital stock in, any corporation involved in defense related production. This infusion of capital was the "shot-in-the-arm" many firms needed to begin expanded production. The RFC would take a mortgage on facilities as security for a loan. If the crisis turned out to be shortlived, the government was to absorb any resulting loss. (23)

The Defense Acts, which allowed the use of defense funds for the purpose of building, equipping, and converting factories to the production of wartime materials, were another government effort to aid industry. The first of the Defense Acts authorized the appropriation of $150 million to expedite production of needed materials. (24) The Second Revenue Act of 1940 and Special Facilities Contracts were also used effectively to expand aircraft production. (25) The Revenue Act was passed with the idea of encouraging contractors to finance their own plant expansion through the use of tax breaks. Special Facility Contracts allowed a company to build and acquire facilities for defense production and, as war materials were produced, the company would file cost statements with the government to obtain reimbursement for its production.

Profits and Controls

The tremendous amounts of money flowing into the production of aircraft raised questions about earnings and profits. For every firm associated with military production, this was a touchy subject. Memories of profiteering during World War I were still strong, and neither the public nor government cared for repetition of that controversy. Apart from a normal patriotic aversion to taking advantage of their nation's needs, responsible businessmen were aware that profiteering would be penalized after, if not during, the war. Once the aircraft program moved into production rates of 50,000 aircraft per year, contract negotiations became guesswork. Few within the War Department had the experience necessary to determine fair prices because of the sheer volume of contracts. Profiteering was a difficult question for all.

The first control to deal with the question of profits was the Vincent-Trammel Act of 1934. Originally set up to limit profits of naval contractors, the act was applied to Army Air Corps contracts in 1939. (26) The Vincent-Trammel Act restricted profits to 10% on contracts negotiated at a fixed price. In 1939 the level was raised to 12%. The efforts of Congress to reduce it to 8% were strongly resisted and, during the summer of 1940, industry almost came to a standstill while Congress debated the issue. Finally, with President Roosevelt's support, the law was liberalized. Even so, British orders, with no profit limits, were preferred to US orders. (27)

The government also made other concessions to industry. Depreciation for tax was allowed to accelerate from 10-16 years to 5 years. An excess profits tax was instituted for fixed profit contracts to encourage greater efficiency. Anti-trust suits were indefinitely postponed. Finally, firms were provided new expansion investment by the government and were allowed to calculate profit rates on the basis of facilities they had not yet built and did not own. This had the advantage of disguising profit levels. The Douglas company, for example, had net profits after tax of 51% of net worth in 1941, yet the overall rate of profit for industry in 1941 was only 7.4%. (28)

Probably the most widely used and accepted method of controlling cost and profit during this period was "renegotiation." (29) Renegotiation consisted of a review of costs of a completed or partially fulfilled contract to determine if profits were excessive. If profits were found to be exceedingly high, arrangements were made to have the excess returned to the government. This technique proved to be an expedient way of recovering funds for the government and a fair way to account for industry inaccuracies in estimating cost due to the unique proportions of wartime production. Renegotiation also eliminated industry's problem of paying higher corporate taxes to cover excess profits. (30)

The Production Record

What were the results of this tremendous industrial effort? By 7 December 1941, the US was the foremost producer of military aircraft in the world. In less than two years, the American aircraft industry had overtaken the other powers of the world in rate of production, despite the head start they enjoyed. The US produced almost 300,000 aircraft in the 62 months between 1 July 1940 and 31 August 1945. During the same period, it turned out 802,161 aircraft engines of all types and 807,424 propellers. The cost of the aircraft program was almost $45 billion, or 24.5% of the total American munitions program of $183 billion. Between 1940 and 1944, when peak production was attained, aircraft manufacture was transformed from a handwork to a mass production industry. During 1940, when the industry was just beginning its expansion, it produced 13,000 aircraft, less than half of them military. In 1944 it turned out more than 96,000 military planes, very nearly 16 times as many as in 1940, and these were generally much larger and more complex than those of the earlier year. Military engine production rose from less than 16,000 engines in 1940 to 256,912 in 1944, more than 16 times over. (Table 1) (31) The monetary value of the finished product increased 30 times over—from approximately $552 million in 1940 to $16,745 million in 1944. The floor space devoted to aircraft manufacture increased during this time perhaps as much as twelvefold (Table 2), and the manpower employed perhaps sixteenfold. (32)

Year	Number of Aircraft	Number of Aero-Engines
1939	5,856	---
1940	12,804	15,513
1941	26,277	58,181
1942	47,836	138,089
1943	85,898	227,116
1944	96,318	256,912
1945	49,761	106,350

Table 1: Aircraft and Aero-Engine Production in the US, 1939-1945.

Date	Airframe	Engine	Propellers
1 January 39	7,479	1,726	250
1 January 40	9,606	3,018	492
1 January 41	17,943	6,463	1,050
1 June 43	77,536	31,829	5,240
December 43	110,423	54,189	6,835
December 44	102,951	54,888	7,888

Table 2: Floor Space for Aircraft and Main Components Manufactured in the US, 1939-44 (000 sq ft).

Conclusion

The joint efforts of business and industry successfully met the challenge facing them in the uncertain hours of 1939 and 1940. The case for the importance of those efforts cannot be overstated as America learned how critical the air arm would be to national security. Three points stand out from the example of World War II. First, there must be adequate preplanning for the possible contingencies of war. Prior to the beginning of World War II, no unified plan or experience for bringing aircraft production up to wartime levels existed. Second, there was not a timely recognition of the magnitude of the buildup which would be required. In the late 1930s and early 1940, it was assumed the aircraft industry could privately finance the necessary expansion. That simply was not the case. It was not until the crisis was imminent that government programs were instituted to finance the expansion of aircraft production. Finally, government mechanisms for administration of the mobilization effort were lacking. During the war buildup, considerable manpower and time were wasted while the government experimented with new approaches to wartime problems.

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Industrial Mobilization as an Element of Logistics

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In the event of a conflict requiring rapid mobilization of the armed forces, there will be a consequent need to mobilize the industrial base to sustain the fighting forces. How well our fighting forces will be sustained in the future clearly depends on our attitude toward industrial mobilization today. How quickly the industrial base will be able to produce the required machinery of war depends on what we do to maintain our industrial base now. Before reviewing the current state of our industrial preparedness, let us review its historic antecedents.

Historical Background

A look at World Wars I and II and their respective postwar periods shows that the key industrial mobilization lessons were—

- Careful allocation and adjustment are necessary to prevent shortages of critical items.
- The numbers and complexity of modern weapons require long lead times and expensive preparations.
- Prior provisions of stores are necessary to support combat until new systems can be produced.

Several critical mobilization developments of the Korean War period still have an impact on industrial preparedness and sustainability.

The Defense Production Act of 1950 (DPA) set in motion the Defense Priorities System (DPS) and the Defense Materials System (DMS). These two systems—amalgamated into the Defense Priorities and Allocations System in July 1984—gave the government authority to require that Department of Defense (DOD) contracts for, or using, strategic metals and materials be given first priority by industry in times of national emergency. This is still an important means of achieving some measure of peacetime mobilization capability.

Title III of the DPA gave agencies concerned with industrial mobilization the authority to extend loans for facilities and capital expansion, research and development, and production of essential materials. Although used extensively throughout the 1950s, use of Title III declined throughout the 1960s until, in 1974, Congress declined to renew its authority when funds were exhausted.

The Vance Committee established the D-to-P concept, which called for a balance between stockpiles and production capability so we would be able to fight on D-day (commencement of operations) with reserves on hand until P-day (when production output catches up to consumption rates).

The response of the military services to the Vance recommendations was halfhearted. Capacity improvement initiatives were underfunded, industrial baselines went cold, and the Air Force rapidly dropped industrial mobilization planning.

Response Philosophy

The reason the Air Force dropped mobilization planning has much to do with the evolution in national strategy from 1947 to 1981. Beginning about 1955, mobilization planning gave way to the doctrine of massive retaliation; this doctrine rested on the then-superior US strategic nuclear delivery capability. Events, however, pointed out that massive retaliation was perceived abroad as an increasingly empty threat and at home as too inflexible given the growing capability of nuclear power to destroy civilization. So during the 1960s and early 1970s, a flexible response doctrine evolved that addressed a wider range of nuclear and conventional options.

Inherent in all these options was the theory that a major modern war, whether nuclear or conventional, would be short. Industrial base planning is largely irrelevant to such thinking, and Vietnam did little to change it. The Nixon administration further deemphasized mobilization by instituting the all-volunteer force concept.

The austere defense budgets of the Carter administration emphasized modernization, causing further degradation of industrial preparedness. D-to-P was replaced by the D+6 policy, which maintained stocks considered adequate for 6 months of combat, notwithstanding whether production rates at that point would meet consumption rates. The Carter administration broadened flexible response but espoused a short-war theory that emphasized stocks on hand over plans to increase production.

With the Reagan administration, the erosion in industrial mobilization planning has begun to be reversed. A new response doctrine of sustained response has been espoused by military theorists, which subsumes and transcends flexible response by emphasizing greater sustainability and thus raising the nuclear threshold (the risk of early resort to nuclear weapons to shore up failing NATO conventional forces). Recently, two theorists at the National Defense University have shown almost conclusively that there is no conceivable war scenario to which sustainment is irrelevant, thus rendering the short-war theory impotent and restoring the D-to-P concept to prominence.

Assessments of the Industrial Base

It is apparent that, during the last 30 years, the United States has become a postindustrial nation, diverting more and more resources into service and information management industries at the expense of basic industry.

This economic evolution, combined with various acquisition policies and practices within the DOD and inadequate incentives for investment in capital equipment, has led to a deterioration of the DOD industrial base. This is

especially true for critical metals and basic materials, and it is also true in intermediate-level production.

In the later years of the Carter administration, attitudes toward mobilization and industrial preparedness began to change. This change was spurred by a growing realization of the unhealthy state of the mobilization base, Soviet aggression in Afghanistan, and a series of mobilization exercises (MOBEXs) from 1978 to 1982 that clearly revealed the unsatisfactory state of the nation's mobilization preparedness.

In December 1980, the House Armed Services Committee Defense Base Industrial Panel (Ichord Panel) issued *The Ailing Defense Industrial Base: Unready for Crisis*. This study surfaced several problems—skilled manpower shortages; increasing reliance on sole sources for critical components (which may be lessening somewhat due to the Competition in Contracting Act); US productivity growth rates that were the lowest among the free world industrialized nations; capital investment constrained by an unfavorable economic, regulatory, and tax environment; serious defense industrial base deficiencies at subcontractor levels; military equipment lead times that were steadily increasing; outmoded production equipment tooling in many industries; and productivity growth rates in the defense sector that were even lower than the overall manufacturing sector.

Clearly, given these deficiencies and the current threat, the United States cannot follow its previous tendency to wait until war is upon it before gearing up industry.

Current Assessment of the Industrial Base

A meaningful current assessment of the defense industrial base distinguishes four levels of US military response to external hostilities—

- *Peacetime purchases,* which establish the current force structure and war reserves.
- *Surge,* which meets emergency demand short of full war and is generally limited to expansion of production within current industrial capacity to cover periods too short to involve industrial mobilization.
- *Mobilization,* including full mobilization, which meets wartime demand and fills out the current program force structure.
- *Total mobilization,* which exceeds the current program force and may approach the planning force in its resource needs, requiring large diversion of civilian goods.

Based on these definitions, I developed an analysis matrix, which I adapted from one developed by Leon Karadbil and Roderick Vawter of the National Defense University (Figure 1). The impacts on sustainability of the intermediate-level problems that surfaced in the Ichord Panel hearings are dramatically reflected in this matrix. It is a critically weak link in the defense industrial base.

TYPE OF INDUSTRIAL ACTIVITY	ABILITY TO MEET DEMAND IN PEACETIME	ABILITY TO MEET DEMAND DURING SURGE	ABILITY TO MEET DEMAND DURING MOBILIZATION
Raw Materials Processing	Normally Yes	Normally Yes	Present Trends Render Unclear
Intermediate Production	Yes, but with Problems	Normally No	No
End Product	Yes	Normally No	No

Figure 1.

The Soviet Defense Industry

By contrast, the Soviet defense industry operates continually at partial mobilization levels, gears facilities to produce military and civilian items simultaneously, trains workers on both, and designs items for quick and easy militarization. It maintains large stockpiles of critical materials and sustains high production rates. Since 1973 the Soviet Union has clearly outproduced the United States in major weapon systems.

The Soviets, many experts agree, will have an initial mobilization advantage over the United States, an advantage that will take 2½ to 3 years to overcome, if it can be overcome at all. The message is clear: the United States must strengthen its commitment to a healthy, relatively independent industrial base that can sustain its forces in conventional combat at least as long as its potential enemies. This would strengthen conventional force deterrence and raise the nuclear threshold.

Proposed and Ongoing Solutions

The Reagan administration has introduced extensive changes into the DOD "modus operandi." In March 1982, then-Deputy Secretary of Defense Carlucci introduced special guidance separate from that contained in the fiscal years 1984-1988 defense guidance, which gave the services objectives related to developing an industrial base capable of surge responsiveness, accelerating the attainment of programmed sustainability for selected critical systems and items, and integrating industrial preparedness resource requirements into the planning, programming, budgeting, and execution system (PPBES) cycle.

Although there has been much planning and training in exercises, such as the industrial responsiveness simulation conducted June-September 1983, still many within industry and the Services complain that little has been accomplished. However, it does appear that funding for industrial preparedness has been included in recent fiscal year appropriations (although an insufficient amount) and is a part of the program objective memorandum and PPBES cycles.

A large stumbling block is industry's perception of DOD's uncertain commitment to mobilization preparedness. Chronic underfunding, understaffing of industrial preparedness elements, inadequate documentation processes, and lack of guidance have frequently been cited by industry to justify a lack of industry attention and progress in this area.

The Office of Management and Budget and the Reagan administration hotly debated the Defense Industrial Base Revitalization Act. Some believed that Act went well beyond the use of DPA Title III funding programs envisioned in the July 1982 National Policy Statement and thus injected too much government intervention in market processes. Such debates have heretofore led to generally anemic congressional funding of such processes as provided for in DPA Title III.

Based on all this, a number of recommendations have been made by analysts in the military schools and elements of DOD for correcting the industrial base problems highlighted. The solutions recommended basically fall into seven categories.

Category 1 - Capitalization Incentives

- Greatly expand and better fund the industrial

modernization improvement program.

- Improve profit and facilities capitalization incentives already available.

Category 2 - Capitalization Funding

- Commit funding for preservation of a warm base for critical materials or items.
- Directly fund efforts to expand facilities where incentives are lacking or inadequate.
- Revitalize Title III loan authority. (This was partially done, though on too restrictive a basis, in 1984.)

Category 3 - Legal and Regulatory Changes

- Initiate standby legislation needed to remove or modify emergency roadblocks quickly.
- Examine and challenge all current and proposed legislation and regulatory language from the point of view of its impact on the industrial base and industrial mobilization.

Category 4 - Stockpiling

- Increase the standby legislation needed to remove or modify emergency roadblocks quickly.
- Stockpile critical assets as well as raw materials.
- Maintain rolling inventories of subcomponents in sub-tier elements known currently to have long lead times.

Category 5 - New Acquisition Methods

- Maximize use of nondevelopmental items.
- Use streamlined acquisition methods.
- Challenge specifications and standards that balloon the size of solicitations and lead times but may not contribute anything relevant to the system under development.
- Incorporate sustainability issues into the integrated logistics process.

Category 6 - Better Planning

- Emphasize lower tiers in every industrial preparedness program.
- Make industrial capability recovery and expansion an integral part of the PPBES cycle at all levels.
- Base more of the planning and programming on *total* mobilization as opposed to the current requirements determination process, which is based on full mobilization.
- Use the Joint Chiefs of Staff planning force as the baseline for mobilization planning instead of the programmed force.

Category 7 - Miscellaneous

- Explore flexible machining systems and other industrial technologies that can greatly reduce lead time, allow rapid switching of production modes and tasks, and thereby increase production capacity without expensive capital and facilities expansion.
- Establish a national policy and goal for mobilization readiness.
- Establish a mobilization readiness czar to coordinate all efforts.
- Establish a congressional focal point for mobilization readiness.
- Make mobilization a benchmark policy against which all other policies are measured.

Conclusion

Many of the proposals made are both workable and cost-effective. Some that are cost-effective may not be feasible because of political considerations or required changes to bureaucratic processes. Others will be *very* costly.

In prioritizing these proposals, we should give highest priority to those that will improve the current state of our industrial base. Second priority should be given to those proposals that will allow us to expand our production capability quickly and efficiently during a period of rapid force mobilization.

Costly though it may be, this nation can no longer afford not to consider combat sustainability over a prolonged period in its requirements and authorizations processes. Time is rapidly becoming our enemy.

(This article was originally published in *Army Logistician*, September-October 1987, and is reprinted with the author's permission.)

Minuteman Missile Facilities Undergo Extensive Updating

Ralph C. Jensen
and
MSgt Timothy L. Miller

Maintenance crews from the Air Force Logistics Command (AFLC) are putting the finishing touches on the first of a series of long overdue overhauls of the launch facilities of the Minuteman missile.

The Rivet MILE (Minuteman Integrated Life Extension) maintenance program features a miniature army of 330 specialists applying their skills to the Minuteman missile's 1,000 aging launch facilities and its 100 launch control facilities.

Unlike the facilities they are housed in, Minuteman missiles have received periodic updates and maintenance since they first went on alert in the 1960s. But with the exception of organizational maintenance performed by Strategic Air Command, the missile silos received little general repair attention. A lot of routine and priority maintenance could not be accomplished over the past two decades due to the lack of resources and impact on alert time. However, there arose serious concerns that 20-25 years after construction, the Minuteman would not be a viable means of defense.

Three separate maintenance cycles are planned under the program with each expected to take three years to complete. Cycle one began in June 1985 and concludes May 31. Cycle two starts June 1. A third cycle begins in 1991. Rivet MILE is managed at Ogden Air Logistics Center, Hill AFB, Utah, in the Materiel Management directorate.

Extracted from AFLC Public Affairs News
Release, Nov 88-27, 17 May 1988

USAF Logistics Policy Insight

Logistics Command and Control (LOG C^2)

The last LOG C^2 Tiger Team met 13-16 June 1988 to review the products and respective benefits of an action plan and then approved the plan for submission to the General Officer Steering Group (GOSG) who was to review and approve the plan. Tiger Team products center around a draft USAF LOG C^2 Concept of Operations, which can be more appropriately called a "workshop manual." It describes the USAF wartime organization, identifies the decision-makers for logistics, and describes the flow of logistics information throughout the organization and the interrelationships of logistics, communications, and automated data processing. The concept should provide the foundation for respective MAJCOM and component C^2 concept development. For more details, contact your LG representative or Wing Commander Alex Buchan, RAF, AF/LEXY, AUTOVON 225-6798 or Lt Col Jon Zall, AUTOVON 225-6785.

AFR 700-26

AFR 700-26, *Acquisition and Management of Small Computers,* is being revised to emphasize consolidating small computer maintenance requirements on a base-wide or regional basis whenever possible. The preferred method is to write a single base-wide or regional service contract to cover all small computers. The contract would be placed through the local Operational Contracting Office and administered by the Base Contracting Officer and Base Communications and Computer Systems Officer. Until a model Performance Work Statement can be developed and incorporated into AFR 400-28, *Base Level Service Contracts,* the contract will be administered IAW AFR 70-9, *Base Level Contract Administration,* procedures. An ancillary issue is that the draft AFR 700-26 will also assign Air Force Communications Command (AFCC) the responsibility for developing small computer maintenance procedures in coordination with host major commands (MAJCOMs) and standard systems managers. (Major Darryl Scott, SAF/AQCO, AUTOVON 224-2679)

Nonappropriated Fund Purchasing Agreements

Appropriated fund contracting offices should take advantage of the pricing available in existing nonappropriated fund purchasing agreements (NPAs). While appropriated fund contracting offices cannot write delivery orders against nonappropriated fund purchasing agreements, they can and should use the pricing and other terms as appropriate. Most contractors with a nonappropriated fund purchasing agreement will honor the same pricing and terms for an appropriate fund order. (Lt Col Stu McGhee, AFMPC/DPMSK, AUTOVON 487-5426)

DRIVE: Distribution and Repair in Variable Environments

DRIVE is a process that prioritizes repair and distribution of recoverable assets to improve aircraft availability. It uses more current data to determine repair, reflects near-term user requirements, provides mission oriented distribution of parts, and ensures returns on investment and get well programs are relevant to current operational needs. Air Force Logistics Command (AFLC) has been prototyping DRIVE at Ogden ALC for over two years to determine repair priorities in the Avionics Integrated Shop (32 LRUs), Analog/Digital Shop (224 SRUs), and Microwave Shop (16 SRUs). Test results have been very impressive and aircraft availability has improved for these items. AFLC is in the process of implementing DRIVE for all repair. DRIVE will be developed by weapon system management information system (WSMIS) for integration with Requirements Data Base (RDB). Full operational capability is scheduled for FY92. Implementation will begin in the Avionics Shops at Ogden and then expand to the Avionics Shops at Warner Robins. While these repair shops are implementing DRIVE, a parallel effort will determine other commodities that will use DRIVE processes. (Lt Col Karen Umberger, HQ USAF/LEXY, AUTOVON 225-1015)

Starting the Quality Revolution in AFLC

"America is on the crest of a quality revolution which has already helped many U.S. manufacturers meet the challenge of foreign competition.... The traditional approach of 'inspecting in quality' is simply too expensive, and doesn't yield the results we must have. That's why we're now shifting our emphasis *away from* evaluating the goods and services we provide at the end of the process, and *toward* the process by which goods and services are actually provided. We need to direct our efforts toward developing processes so good that, in terms of what they produce, there are no deficiencies to detect, no flaws to correct, and thus, no need for quality inspections in the first place."

General Alfred G. Hansen
Commander, AFLC

Space Logistics Technology - The New Challenge

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Introduction

Space logistics presents unique requirements. Although these requirements are new, they can be met by an extension of basic logistics principles. However, new terminology and analytical tools are required to refine the application of these principles. Space logistics issues occur in two major areas: space-based asset support and support of the ground-based segments of space systems.

In the future, space-based assets may require both routine servicing and corrective maintenance. The means of meeting these potential requirements can vary greatly depending on the type of orbit in which the asset is deployed. Servicing is the routine replenishment of consumables such as batteries, fuel, and cryogenic materials. Maintenance includes the modular upgrade of components as well as repair of failed items. This paper details the type of servicing future space-based assets may require. Modes of maintenance for space-based assets, such as robotic on-orbit repair, remove and return to orbit, and on-orbit self-correction are also discussed.

Never has the need for logistics engineering been so great as it is today in the design of space systems. Supportability factors require the establishment of major design constraints on space vehicles. The design constraints on operational vehicles must be balanced against the complexity required on servicing vehicles. Storage of repairables; packaging, handling, and transportation restrictions of space deliveries; and return of failed units for repair are factors to be addressed in establishing the design of a space system support structure.

Supportability of ground-based space systems also presents some unique logistics problems. The reliability of ground assets which control space systems is critical. These assets vary from tracking, telementry, and control facilities to launch facilities.

The analytical tools currently available to assist in making those difficult cost, schedule, performance, and supportability trade-offs are fragmented and do not cover all necessary factors. This paper examines the tools currently available to support logistics analysis of space systems. Deficiencies in these tools are identified and a course of action to develop integrated tools and to mitigate the effects of inadequacies in current tools is proposed.

Space Logistics

Although standard logistics principles apply to the space environment, the uniqueness of the space environment requires application of specialized technical knowledge. The standard analytical tools and techniques used for nonspace systems fall short of meeting space requirements. A restructuring of the way we approach design and support of space systems is required.

Initially, space programs were treated both by industry and the government as basically research and development efforts. "High technology and small quantities of equipment characterized most programs." (1) As space systems became more plentiful, the contractor community established a basic space logistics infrastructure. With the growth of the Air Force space budget (doubling from 1980 to 1983 and tripling by 1986), the Air Force recognized the need to reexamine how it performed space logistics functions. As early as 1982, the Air Force established this objective: "The Air Force must develop a logistics support capability commensurate with the evolving military operations in space." (2) The establishment of the Air Force Space Command was another revolutionary step from ". . . the need to consolidate what was becoming an increasingly diverse and complex Air Force Space Program." (3)

The Air Force in conjunction with industry has undertaken several study efforts to determine the various options available for establishment of logistics infrastraucture to support routine space operations. This effort required an examination of four separate segments of space systems: space, launch, control, and user. The space segment is comprised of the satellites. The launch segment includes the launch vehicle, payload processing at the launch site, and the ranges themselves. The control segment consists of telemetry, tracking, and commanding (TT&C) of the satellite. The user segment includes those activities that use the mission data from the satellite. (4) For the purpose of this paper, our discussion will address the difference between the space-based and ground-based portions of these segments of the space logistics system.

Space-Based Segment

The area of greatest challenge and interest is, of course, in the space-based portions of space systems. The visions of robotic repair vehicles performing on-orbit repair, space platforms or space stations performing spare parts storage and repair functions, space maintenance technicians using technical data projected on an in-helmet "heads-up display" (HUD), self-torquing wrenches, and self-repairing satellites using artificial intelligence logic can quickly fire the imagination of a space logistician. The opportunities for a logistic engineer are virtually unlimited.

When we come down to the practicality of how to design a specific space system, we are confronted with a severe lack of tools to assist in making those design decisions that affect supportability and life cycle costs. Normally, government contracts will specify the use of MIL-STD-1388-1A and MIL-STD-1388-2A as the analysis process and data processing tool to perform logistics support analysis. A review of these standards quickly reveals a critical lack of software

supportability factors and data elements and the nonexistence of any space peculiar factors.

What factors should be included and what is being done to qualify them? To answer the first question we need to examine the type of functions that must be performed in space and the alternative methods of performing them. The basic space peculiar functions are assembly, maintenance, and servicing. Space assembly is the process where components of a space-based system (a space station) are deposited in orbit by one or more launch vehicles and then assembled into a complete space unit. Space maintenance is the process by which preventive or corrective maintenance actions are performed on a space-based system. Space servicing includes replenishing fuel or cryogenic material, or charging/replacing batteries.

Space assembly factors include the method of launch, the number of launch vehicles required, complexity of rendezvous and docking, modular design, solar orientation, manpower, space tools, personnel support, space support equipment, robotics, and time required.

Space maintenance factors include a combination of the normal ground environment maintenance factors and the peculiar factors associated with space assembly. Simple factors such as how do we get the maintenance man or device to the equipment become exceedingly complex in the space environment. There are many possible methods of placing a servicing vehicle in the same orbital position as a mission vehicle. Three basic techniques relevant to on-orbit maintenance are the Hohmann transfer, apogee transfer, and perigee transfer.

The Hohmann transfer (Figure 1) will take a servicing vehicle from its lower orbit (Radius R1) and increase its altitude to place it in the higher orbit (Radius R2) which is coincident with orbit of the vehicle requiring servicing. At the perigee (point closest to the earth) of the transfer orbit (Point P), boost is applied to the servicing vehicle. This increases its orbital velocity by delta V1. This puts the vehicle on an elliptical path towards the apogee (point farthest from the earth) of the transfer orbit (Point A). As the servicer reaches its apogee at Point A, an additional boost is applied, increasing its velocity by delta V2. The new velocity results in circularizing the servicer's orbit at R2. If the ratio of the radii $R2/R1 < 11.94$, the Hohmann Maneuver is the most fuel efficient one to execute.

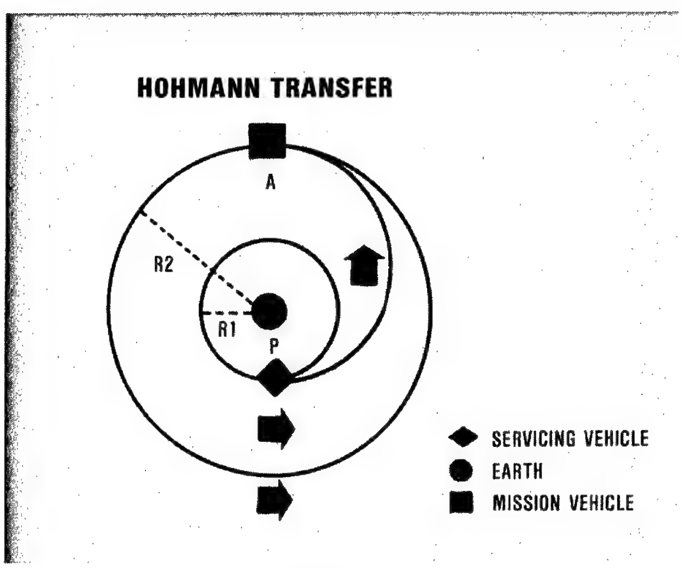

Figure 1.

Once the servicing vehicle has obtained the same orbit as the mission vehicle to be serviced, a new set of problems arises. If the servicing vehicle is trailing the mission satellite, it must "catch up." The servicing vehicle cannot "speed up" since this would result in a new orbit at a higher altitude. Instead a maneuver called apogee transfer must be initiated.

The apogee transfer is based on the principle of changing orbital position by placing the powered vehicle on an elliptical path which has a different orbital period than the circular orbit of the mission vehicle. After one revolution, the vehicle returns to its original orbit at the apogee of the elliptical transfer orbit (Figure 2).

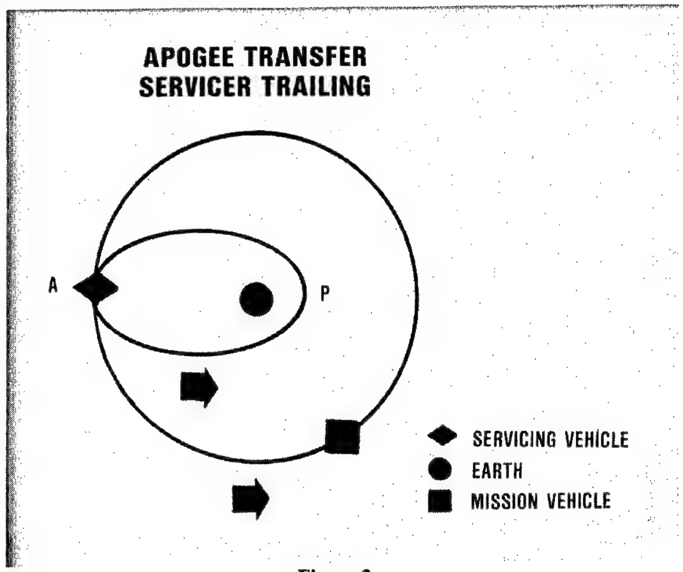

Figure 2.

We will assume the servicing vehicle is trailing the object to be serviced. At Point A the servicing vehicle reduces its speed by delta V1. This places the servicer on an elliptical path. By adjusting the magnitude of delta V1, one can time the period of its orbit to allow it to meet the object to be serviced.

When the servicer completes its elliptical orbit by arriving back at Point A, a boost is applied to increase its velocity by delta V2 ($V2 = -V1$). This change in velocity places the servicer back in its original orbit but in a position in which it is able to dock with the mission vehicle. So in the apogee transfer, the servicer must paradoxically slow down to "catch up" with the object to be serviced.

If the angular separation of the servicer to the mission vehicle is such that the servicer is "ahead" of the mission vehicle, the perigee transfer maneuver is executed. The crossover point for when to conduct an apogee or perigee transfer occurs at approximately 128.4 degrees of angular separation. For angles greater than 128.4 degrees, it is more efficient to execute a one revolution transfer using the perigee transfer maneuver.

The perigee transfer is based on the same principle as the apogee transfer (using an elliptical path with a different orbital period). As shown in Figure 3, the servicing vehicle increases its velocity at Point P by delta V1. This places the servicer in an elliptical path that lies outside the mission vehicle's circular orbit. The time required to complete the larger, elliptical orbit is greater than that of the circular path.

When the servicer has completed its elliptical revolution, it has "caught up" and meets the mission vehicle at the perigee

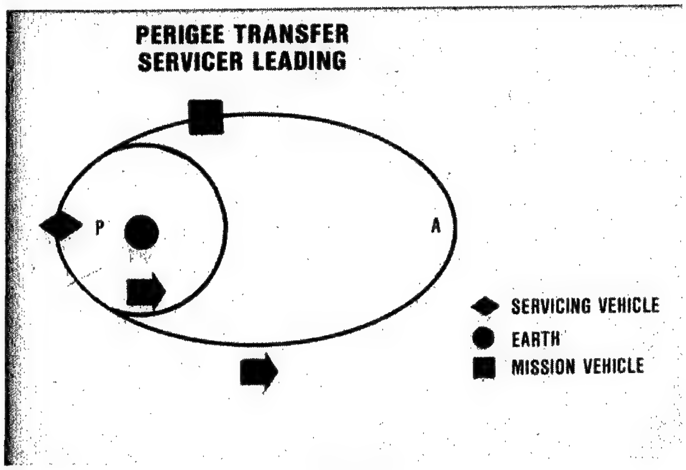

Figure 3.

of its transfer orbit. At the point (Point P) it slows its velocity by delta V2 where $V2 = -V1$. The circular orbit of the servicer is restored and both vehicles are in the same orbital position.

So, as with apogee transfer one must again do the paradoxical. To "slow down" the servicing vehicle to allow the mission vehicle to catch up with it, one must speed it up.

Although our discussion is based on a one-orbit transfer, the same results can be achieved by executing either the apogee or perigee transfer maneuver several times with smaller delta Vs. The single revolution transfer is the most time efficient with the multiple revolution transfer being the most fuel efficient.

The three techniques described are based on the premise that we start with circular, concentric orbits. If these conditions do not exist, then the calculations and potential problems become more complex. This is especially true if the orbits involved are not coplanar (in the same orbital plane).

How to use a servicing vehicle to maintain a constellation of like satellites located in different orbital planes is one of the more challenging issues facing the space logistician. If the degree of change is anything more than a few degrees, the fuel required to make the maneuver becomes the limiting factor. If we decide to perform the maintenance using technicians, the cost of bringing along a life support environment becomes significant.

To overcome or mitigate the constraints described, unique maintenance approaches must be developed. The new approaches also have unique support factors to consider. We could develop self-maintaining satellites (SMS). SMS could use artificial intelligence (AI) logic to route around failed components. This approach would be feasible for modules or functions composed of very high speed integrated circuits (VHSIC). The satellite would in essence reconfigure its electronic circuitry by reallocating functions. If a total SMS is not feasible, the same function changes could be programmed from a ground-based maintenance terminal.

Software maintenance in the space environment also poses some unique problems. We probably will not have the luxury of program development tools, text editors, and compilers to perform software maintenance in space. We will need some means of loading compiled changes into the operational satellite either from the ground or from magnetic media in space. Physical replacement of firmware may be required. Space servicing factors include docking requirements (contact point, antennae and solar panel locations), interfaces between servicing and mission vehicles (cryogenic fluid connections, electrical connections), and environmental factors (solar heating effect, zero gravity transfer).

What is being done to quantify software and space peculiar factors? The Air Force in association with industry has several ongoing efforts. These efforts are aimed at various segments of the overall problem. Some efforts are identifying cost trade-off factors associated with manned versus unmanned repair. Other studies are identifying on-orbit support issues such as technical data formats and space unique tool and support equipment requirements. Additional efforts are exploring space assembly and maintenance and servicing functions.

In the software arena various educational institutions are addressing the software supportability issue. The Department of Defense is refining its standards for software development and support. The use of the higher order language ADA is expected to improve software supportability.

Despite these ongoing efforts, we have not yet reached a point where we can establish a coherent set of data elements, definitions, formats, and algorithms for these factors. Our efforts must continue and be integrated into a coherent whole. Once integrated, they can be formalized into such documents as MIL-STD-1388-1A and MIL-STD-1388-2A and used to influence design and to determine support requirements.

Launch Segment

The launch segment in simplistic terms is nothing more than a transportation system for delivering the mission equipment and spares to their final destination and the return of repairables to the intermediate or depot level repair facility. For the multitude of land-based systems, this area of logistics normally gets only cursory attention. When we talk about a space-based system, we may be talking about a destination that is 22,000 statute miles away from the earth and a multi-million dollar freight bill. Transportation logistics takes on a new meaning.

In my definition of the launch segment, I include not only the support required to launch a satellite physically, but also the logistics of getting the satellite to the launch pad, and the process required to land and "turn around" a reusable transportation vehicle. Since we have tended to treat space launches as a research and development effort, we normally did not concern ourselves with establishing a "normalized" logistics infrastructure.

Another factor associated with the logistics of the launch segment is the location of the launch site. Launches from the coast of Florida eastward over the water have the capability of carrying a significantly larger payload than launches from the West Coast of California. To avoid any potential problems of debris, West Coast launches are to the south or the west. A launch to the west will result in a retrograde orbit. This is an orbit counter to the rotation of the earth and therefore only able to carry a reduced payload for the same fuel.

The economies of scale that are present in the manufacture of large quantities of identical items have not yet reached the launch segment. Until these are economies approached, the launch segment will probably remain the costly element of space systems and will have the most significant impact on maintenance concepts.

Control Segment

The control segment is the ground-based link to the satellite that controls its movement and receives information about the satellite's position. The three main functions of the control segment are telemetry, tracking, and commanding (TT&C).

These functions perform corrections in orbit, are used for collision avoidance, and keep track of the satellite's location. The factors associated with the control segment include the type and period of orbit.

If a satellite is in geosynchronous orbit (has a 24-hour period and appears fixed relative to equator), the problem of establishing the location of ground stations is simplified. The other extreme is a sun-synchronous orbit (a retrograde orbit in which at a specific local time each day, the satellite will be in the same latitude with respect to the sun and earth). Other types of orbits include circular, elliptical, and semi-synchronous ground trace orbits. Each of these types of orbits has different loiter times over ground control stations. The mission reliability of each ground station must be high enough to cover the time the satellite must be in contact with the ground station. Redundancy of ground stations may be required to meet mission reliability requirements.

The period of a satellite is the time it takes to complete one orbit. If a satellite is not in a geosynchronous orbit, it will take a specified time before it returns over a ground control station. It this ground station is serving only one satellite, its mean time to repair should be less than the time it takes for the satellite to return.

As you can see, the simple factors of type and period of orbit can have a significant impact on the logistics requirements for control segment ground stations. These are in addition to the normal logistics factors related to ground communications electronic systems.

User Segment

The user segment is composed of those activities that use the data collected from space-based assets. The whole purpose of having our present space systems is to provide information to the user. A communication, weather, or geodesic survey satellite is useless, unless the data it collects is passed to the user. Factors affecting logistics support of the user segment include the number and information requirements of users, and the time sensitivity of the information.

One satellite might contain a multitude of sensors or communication circuits. Each of these sensors or circuits may have different end users with different data format requirements. The ground stations must be designed to handle these varying requirements in a cost-effective way. In one sense we just have a transportation problem of how to "deliver" a product to the consumer.

As with any transportation problems, we are concerned with mode of transportation, origin and destination of the shipment, and packaging and handling requirements. Our mode of transportation is a data link through a ground station. Our origin is space and our destinations are the various locations of the end users. Our packaging and handling requirements are the data rate and protocols required.

The location of end users is a factor since some additional relay circuits and multiple ground terminals may be required to meet mission requirements. A change in the location of a ground terminal or the end user may result in a significant cost impact.

Some people would perceive this as a communications engineering problem and not a logistics problem. Logistics factors which should influence the design include hardware and software maintenance problems created if we do not standardize on data format and processors at a ground station which serves more than one sensor or end user, training and manpower to support various locations, reliability requirements based on time sensitivity of data, and the need for redundancy and correlation of data from various ground stations.

Synergistic Logistics

Although we have discussed the factors related to each of the segments of a space system (space, launch, control, and user), we cannot treat them individually when we perform our logistics analysis. We may have to suboptimize a factor in one segment to achieve gains in supportability and availability overall. So not only must we trade cost, schedule, and performance factors with logistics factors to achieve the best overall system, we must also trade logistics factors with each other.

Our record of success in achieving this in normal ground systems is not good. Only recently have we begun to get management's attention on the importance of logistics during the design process. Management attention is not sufficient to achieve results. We must also provide design tools to the system engineer so logistics factors can be quantified and evaluated during design. Our current tools fall far short of this requirement.

Logistics Tool Deficiencies

A recent Air Staff study of logistics support analysis/logistics support analysis record (LSA/LSAR) identified many major deficiencies in the current LSA process. Active participation by industry was instrumental in the success of this study effort. Major areas identified as problems were inadequate or inappropriate program application, insufficient training, lack of an integrated policy, and an inadequate data system.

As presently structured, MIL-STD-1388-1A and MIL-STD-1388-2A are primarily hardware oriented. There is a lack of both system perspective and software factors. A review of Appendix E to MIL-STD-1388-2A shows the incompatibility of LSAR output reports to standard contract data requirements. Use of these reports as part of the design effort is often inefficient. For instance, to prepare the Task and Skill Analysis Report, you must run and analyze 16 different output reports. Common use of data for reliability prediction and modeling, repair level analysis, and life cycle costing is hampered by model incompatibility in data elements, formats, and definitions.

The space peculiar factors discussed in this paper are not included in currently approved logistics models. New data elements, definitions, algorithms, and output reports must be created.

Plan of Action

The Air Force Acquisition Review Group Report on LSA/LSAR proposed many meaningful corrective actions. Implementation of these recommendations will help to improve the LSA process significantly. The Computer Aided Logistics Support (CALS) program initiated by DOD will also improve the tools we have available. One issue that the CALS program is looking at is the establishment of "neutral data elements, formats and definitions" to allow cross utilization of data by the designer, user, and supporter from a common data base.

Government, industry, and joint independent research projects are on-going which address various aspects of space peculiar logistics. These efforts must be continued and integrated. Potential forums to assist in this effort are the Government/Industry LSA Panel and the various conferences and symposiums offered the Society of Logistics Engineers (SOLE). The establishment of a subpanel on space logistics under the Government/Industry LSA Panel should be explored. Expansion of SOLE's effort in logistics education to include the establishment of blocks of instruction in engineering and logistics management courses on space logistics could help.

Summary

Application of logistics support analysis principles to the design and support of space systems is critical if we are to have cost effective and supportable space systems. Current logistics support analysis tools do not support developing a synergistic approach to total system design or the design of a support infrastructure. Most logistics support analysis models are hardware, not system oriented. In the area of space logistics, software support is of paramount importance and is a significant life cycle cost driver. There are significant opportunities to minimize life cycle maintenance costs by using both ground-based and space-based software to correct or compensate for hardware and software failures.

Integration of logistics support analysis models with life cycle cost, reliability predictions, and repair level analysis models is at a rudimentary level. The lack of common data element definitions and formats, as well as the lack of standard data interfaces, severely limits their effectiveness. The model themselves do not currently include the space peculiar support parameters.

This paper addressed some of the space peculiar factors we must consider. The impact of logistics on space systems covers all segments, and integration across segments is required. Definitions and application of space peculiar factors are on-going at a rudimentary level. These efforts must be continued and integrated. Industry and government must work together to achieve this goal.

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The original version of this article first appeared in the 22nd Annual Proceedings of the Society of Logistics Engineers, but the article has been revised for publication in the *AFJL*.

Continued From Page 25

Assembly Line for B-24 "Liberator" Bomber at Consolidated Aircraft Company Plant, Fort Worth, Texas.

Technology has brought us into a new age of warfare; however, the relationship between government and industry in managing the nation's industrial base remains as important now as it was in 1940. Have we learned over the years? Will Fortress America be prepared for the next challenge?

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"When looking at military excellence, it's important to understand that, like any excellence, it's a product of capability, effort, and momentum."

The Defense Matrix by General James P. Mullins, USAF (Ret)

CURRENT RESEARCH

AFIT School of Systems and Logistics Completed Theses and Follow-on Research Opportunities

(Continued from Spring issue)

The Air Force Institute of Technology's thesis research program is an integral part of the graduate education program within the School of Systems and Logistics. The graduate thesis research program is designed to contribute to the educational mission of AFIT's Graduate Program through attainment of the following specific objectives:

(1) Give the student the opportunity to gain experience in problem analysis, independent research, and concise, comprehensible written expression.

(2) Enhance the student's knowledge in a specialized area and increase the student's understanding of the general logistics environment.

(3) Increase the professional capabilities and stature of faculty members in their fields of study.

(4) Identify military management problems and contribute to the body of knowledge in the field of military management.

Organizations that have potential research topics in the areas of logistics management, systems management, engineering management, and contracting/manufacturing management may submit the topics direct to the School of Systems and Logistics, Air Force Institute of Technology (Lt Col Gary L. Delaney, AUTOVON 785-4845).

The graduate theses listed in this article were completed by Class 1986S of the Air Force Institute of Technology's School of Systems and Logistics. AFIT Class 1986S theses are presently on file with the Defense Logistics Studies Information Exchange (DLSIE) and the Defense Technical Information Center (DTIC).

Organizations interested in obtaining a copy of a thesis should make the request direct to either DLSIE or DTIC, not to AFIT. The "AD" number included with each graduate thesis is the control number that should be used when requesting a copy of a thesis from DTIC. The "LD" number should be used when ordering from DLSIE.

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(Continued in the Fall issue)

Cost Comparisons Within Civil Engineering Functions: Contract or In-house?

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Background

Since 1979, the Air Force has been a pioneer in advancing the concept of performing selected peacetime functions through contracted resources. This article discusses the experience with contracted civil engineering functions, recognizing that such operations as aircraft maintenance, base services, and other commercially-available activities have also been successfully contracted.

The contracting-out program is administered under procedures detailed in the Office of Management and Budget (OMB) Circular A-76, with these objectives:

(1) To achieve economy and enhance productivity.

(2) To retain government functions in-house.

(3) To promote free enterprise and the use of commercial services by the government and to perform commercial activities as economically as possible.

Awards for prospective jobs are based on an economic comparison of contractor bids versus government costs in accordance with performance-oriented statement of work criteria. Whether the results were to retain the in-house work force or to award a contract to perform the function, A-76 cost comparisons have generally saved money. Contracts also allow government manpower to be reallocated to other functions. Economy is one of the goals of an A-76 policy. To the managing function however—and indeed to the Air Force overall—a procedure that saves dollars but accepts inferior service is far from economical.

In most cases, A-76 cost comparisons have resulted in contracts or in-house operations which were responsive, provided quality products, and were more efficient than the previous operations. For bases and functions that were not so fortunate, the A-76 program has had costly and counterproductive results, some with the potential to affect mission accomplishment. What happened? How did these failures occur, and what did they cost the government? Is there a way to prevent similar problems?

Although A-76 procedures have many built-in safeguards, many of the problems experienced were due to errors or omissions in performance work statement (PWS) preparation and review, or to poor quality assurance after award. Some failures have been attributable to contractor performance.

Cost Comparisons Within CE Functions

Within Air Force Civil Engineering, the functions designated for A-76 cost comparisons are grounds maintenance, protective coating, military family housing (MFH) maintenance, and refuse collection. Military Airlift Command (MAC) bases have had success with most of their contracts, with some notable exceptions. Those exceptions vary widely in degree of dissatisfaction and impact on mission support or quality of life.

Grounds Maintenance

With regard to grounds maintenance, two bases won the option to maintain the function in-house and are providing excellent grounds maintenance. However, the two bases that converted to contract have had significant problems. At one base, responsiveness is average, but contract costs increase daily as tasks are identified which were not included in the original PWS. The modifications have generally been minor, such as specifying finished work associated with tree pruning. Over the course of three years, however, contract modifications costing $100,000 have been necessary to clarify such task requirements. Thus, the low bid used for the cost comparison is no longer a meaningful evaluation factor. At the other base, a contractor initially performed well, but is now providing minimal service. The quality of work is poor, and government management time is excessive.

Protective Coating

Six MAC bases are very pleased with their protective coating (painting) contracts. Several attribute this to cooperative contractors who are motivated to perform quality work despite a weak statement of work. Two bases, however, have had less desirable experiences. At one base, the contractor underestimated the number of small detailed jobs, expecting instead to paint large areas. Since this contractor cannot realize a profit based on bid price, work quality and responsiveness are suffering. An example of poor work was a recent job to refinish the gymnasium floor, which required closing the gym for two weeks. The work had to be redone three times due to inferior quality, and the gym was finally opened six weeks later. At a second base, two consecutive contractors have been awarded only the basic one-year contract. Options to extend were not exercised because of poor performance. Consistently late completion of work, frequently accompanied by contention over such details as the extent of surface preparation, plagued the contract QAE and displeased customers. Two years of poor service have had a lasting effect on facility life, and excessive time has been lost in contract management effort.

MFH Maintenance

The quality of service for MFH maintenance contracts varies with each MAC base. Three bases have contracts which are providing superb service, and they will continue exercising contract options with those contractors. Some bases, however, have faced major challenges. At one base, contractor A was

defaulted by the government in 1985 for nonperformance and other associated problems. Subsequent award to contractor B was not continued beyond the basic year because of poor performance. As a third new contract has not yet been awarded, the base has been performing this function since September 1987 with temporary overhire employees. The "overhires" are providing the first acceptable service the base has enjoyed in years! Additionally, the default of contractor A prevented other MAC bases from extending contract options to that contractor. This caused a short-notice requirement to perform this function with temporary employees at those bases, until a new contract could be advertised and awarded.

Refuse Collection

Fortunately, refuse collection contracts have been generally satisfactory. This function is easily isolated from other civil engineering work and is readily available as a commercial service.

Consequences Resulting from Poor Performance

Situations of the magnitude described have *cost* the government a great deal, not only in money but in other areas as well. These costs are far greater than increased management time:

Opportunity Loss: When a contractor is defaulted, other resources must be realigned to support that function. Although the work force itself can be overhired, the government must train the new personnel. Vehicles, radios, and tools previously provided by the contractor must now be borrowed from other shops. This creates a shortage in all affected areas, decreasing productivity and customer satisfaction. Although these situations are "temporary" until a new contract can be awarded, they sometimes last for months.

Inefficiency: Coordination of scheduling with other shops can affect the progress of large multicraft projects, since grounds maintenance and protective coating are frequently involved. Poor contractors have often caused delays in work progress, affecting the productivity of other shops. At a base where the government decided not to exercise the option for a protective coating contract, the contractor kept only one employee on base during the last month of the contract. All work orders requiring painting were delayed until the contract expired.

Image: Customers and commanders expect quality service, and the image of the entire civil engineering organization plummets when such visible services as MFH maintenance and grounds maintenance are substandard.

Responsiveness: Without in-house resources, response capabilities for unusual requirements are limited or nonexistent. Contingency clauses can never be all-encompassing. Natural disasters, commander and special interest projects, and other unforeseen situations requiring immediate responses are a tremendous challenge when in-house resources do not exist. Even the most responsive contractors do not offer the flexibility of an in-house work force.

Real Property Deterioration: Failure to maintain grounds properly can lead to the loss of grassy areas, as well as the development of health hazards from overgrowth and build-up of debris. Failure to maintain the protective coating program adequately can lead to rapid deterioration of facilities. Recovery from long periods of neglect is expensive, time-consuming, and preventable.

Actual Dollars Expended: In some cases, the government estimate may have been based on knowledge of workload which was not adequately specified in the PWS. Thus, initial low contractor bids were rapidly increased through contract modifications to include tasks not included in the PWS and through subsequent increases in contract costs for option years. As mentioned earlier, one contract increased almost $100,000—over 20% of the original contract amount. Although the initial bid was lower than in-house government costs, "economy" in this case became meaningless.

Problems/Solutions

The circumstances that led to situations of this sort differ from base to base, and between functions at each base. However, the primary culprit has been a poor PWS, aggravated by inadequate job analysis during its development. Often, the PWS did not accurately describe the tasks and level of effort necessary to accomplish the required work. For example, one civil engineer assumed that surface preparation for trim painting included removal of window air conditioners, but did not specifically state this in the PWS. Although the civil engineer intuitively included this task in the critical workload data for the government bid, the contractor contested it, and a modification was required to include removal of window units. Another contract provided an estimated quantity of work for a bid item, but did not specify whether that quantity applied for one month, a year, or three years. The government workload data was based on a one-year period, but the contractor contended that he had bid based on the lower frequency of work, and the contract had to be modified to clarify the time period. PWS provisions are often inadequate to allow for good contract bids and subsequent contract administration. The best safeguard is inclusion of detailed information on critical workload data to ensure bids are based on realistic expectations.

Some bases employed poor quality assurance evaluation and contract administration, resulting in contractor noncompliance with the PWS. In some cases, this led to significant payment for services not received and nonenforcement of liquidated damages and reinspection clauses.

Most problems with A-76 contracts can be avoided by ensuring the PWS is accurate, contract surveillance is thorough and well-documented, and contract provisions are enforced. These actions will not help if the contractor is simply not a performer, but they can minimize the impact and potentially improve the performance of a borderline contractor. Unfortunately, poor contractors may be the apparent low bidders on some contracts. Careful evaluations of proposals and contractor qualifications are the only defense.

One way to ensure responsiveness is to retain the function in-house. This requires careful attention during the A-76 cost comparison process. The most efficient organization (MEO) for each function—the leanest possible in-house work force, used for the government "bid"—must be precisely derived, and must use a workload/frequency identical to the minimum essential services/frequencies identified in the PWS. Proper attention to all aspects of development of the MEO and PWS has led to considerable success within MAC in retaining functions in-house following cost comparisons. MAC cost comparisons have resulted in contracts for only 53% of the

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CAREER AND PERSONNEL INFORMATION

Civilian Career Management

Developing Tomorrow's Logistics Work Force

The Logistics Civilian Career Enhancement Program (LCCEP) strives to develop future leaders of the logistics work force through a number of career development opportunities and training programs:

- PALACE ACQUIRE (PAQ) Intern Program
- Presidential Management Intern (PMI) Program
- Office of the Assistant Secretary of Defense Professional Enhancement Program (OASD PEP)
- Education with Industry (EWI) Program
- Career Broadening Program
- Long-Term Full-Time (LTFT) Training Programs
- Short-Term Training Courses

The PAQ and PMI programs are designed to attract recent college graduates who exhibit the potential to succeed in the logistics work force. The gaining organization provides on-the-job training over a two- or three-year training period with progressively challenging duties. The career programs also provide Air Force-sponsored training courses in the assigned career specialty to further enhance technical or management skills. Upon reaching the target grade, the PAQ and PMI interns complete the training programs and are placed in permanent Air Force logistics positions, making effective use of their training. These programs have been very successful in identifying the high potential leaders of tomorrow while also bringing recent academic acumen to the Air Force.

The OASD PEP, EWI, career broadening program, and LTFT assignments offer program registrants many opportunities to enhance their career experiences. Registrants can apply to work in selected areas of logistics to gain a broader logistics perspective at different major commands or at Headquarters USAF level. In addition, academic programs toward a degree will further enhance the work force for future managerial challenges.

Short-term training, to further develop leadership and managerial skills, is also offered through LCCEP. Approximately 15 courses are available at various locations around the country and in Europe. These courses vary in length from three to five days and are designed to improve logistics managers' skills and prepare them to execute their future leadership roles more effectively.

The LCCEP has provided significant opportunities for logisticians to progress in their career. From FY80 to FY87, 24 out of 44 LCCEP career broadeners were promoted and another 12 received career enrichment assignments. Of the 24 LCCEP registrants who have completed the OASD Professional Enhancement Program during 1981 to 1987, 12 were promoted, while three received enrichment assignments. The statistics for registrants who received their graduate degrees through the LCCEP also indicate almost 60% have been promoted. Those who have completed one of the career broadening opportunities have enjoyed the visibility of Air Force leaders as well as a higher promotion rate.

LCCEP participants have received significant opportunities for promotion subsequent to the completion of these programs; PAQ and PMI interns qualify upon completion of their training programs and subsequently qualify for LCCEP-managed positions. The ultimate intent of these career broadening opportunities is to increase the work experiences and skills of logisticians, which in the process has made them more competitive for promotion. Approximately 10% of the registrants in the logistics work force are promoted each year. In comparison, approximately 50% of LCCEP registrants who complete a long-term career broadening assignment are promoted.

Even though Fiscal Year 1988 (FY88) will be remembered as the year of big budget cuts, it can also be remembered as a record year for career advancement and promotions for LCCEP registrants. By 31 March 1988, a total of 105 promotions and 12 reassignments had been completed through the LCCEP candidate referral process.

LCCEP PROMOTIONS AND REASSIGNMENTS

	COMMAND							
GRADE	TAC	AFLC	USAFE	MAC	CPC	AFSC	OTHER	TOTAL
GS-09							2/-	2/-
GS-11		1/-						1/-
GS-12	1/-	30/4	1/-	1/1	-/1	5/-	1/2	39/8
GS/GM-13	4/-	18/-	2/-	1/-		4/2	2/-	31/2
GS/GM-14		21/-		1/1	-/1	1/-	2/-	25/2
GM-15		6/-		1/-				7/-
TOTALS	5/-	76/4	3/-	4/2	-/2	10/2	7/2	105/12

Certificate selections are shown by command and grade. The number on the left represents promotions and the number on the right represents reassignments.

Figure 1.

Of those selected, 23 selections resulted in a PCS move from one geographical location to another. While major commands have experienced austere PCS funding, LCCEP PCS funds were still available to refer the most qualified Air Force-wide candidates for consideration.

Several of the promotion or reassignment actions involved movement between a wholesale function (Air Force Logistics Command) and a retail function (all other commands). During the period 1 October 1987 to 31 March 1988, there have been 12 promotions or reassignments resulting in moves between wholesale and retail functions in logistics, general supply, and freight and traffic management.

The LCCEP continues to be a significant factor for Air Force logisticians in meeting the greater managerial challenges of tomorrow. The logisticians of tomorrow are the motivated people of today who willingly participate in these training programs and career broadening opportunities to gain the broader perspective needed to be a leader in tomorrow's Air Force.

We are proud of the LCCEP success in training, developing, and sustaining the Air Force's civilian resources. With your new ideas and continued help, we resolve to perpetuate improvements and refinements in the program. The LCCEP program will continue to provide these opportunities for logisticians to train and career broaden to achieve their career goals.

(AFCPMC/DPCML, Randolph AFB TX/AV 487-2498)

LOGISTICS WARRIORS

Logistics of the Past - Manpower in World War II

Without doubt, manpower is likely the most important single element in the complex formula for creating and sustaining military capability. If we were to define logistics as that system established to create and sustain military capability, we would have to agree that manpower must be part of that system. Yet, the Services and the Department of Defense fail to recognize and include manpower as a part of logistics.

Certainly, wars cannot be won without manpower, and military capability cannot exist without it. Therefore, the consideration of manpower in wartime is of prime importance to the logistician. For that reason, I thought there might be interest in a brief review of the manpower situation in World War II. We haven't the space to review the participation of both men and women in business, industry, and the military in WWII, so this article will be limited to male manpower. The role of females in WWII might be the subject of another article later.

The Build-up

In the 1930s our country believed a large military force was not necessary. We had no intention of interfering with the affairs of other nations because we felt we had enough to do to take care of our own internal affairs, especially coping with the effects of the great depression. We practiced isolationism—a separation from the activities of the rest of the world. Further, we had the luxury of what was known as "the two-ocean separation" which provided security and freedom from instant attack from potential enemies to the East or West. We had no problems with either Canada or Mexico and felt no threat from our contiguous neighbors.

Thus, military forces were small and were charged primarily with the defense of the continental United States. With small manpower authorizations from Congress came small budgets and little or no new equipment. The authorized strength of the combined Army and Navy in the late 1930s was about 330,000 men. Filling those spaces was easily accomplished through voluntary enlistments.

But, on 1 September 1939, Germany invaded Poland and what we have come to call "World War II" began. Because of existing security agreements, the British and the French responded with armed forces to assist the Poles. As the might of the German armed forces became more evident and the losses of the British and French more severe, the US began to recognize a need for strengthening our own military. When, in the Spring of 1940, the British had to evacuate all allied troops from the continent because of the entrapment at Dunkirk, Congress became even more concerned. Almost immediately, Paris fell to the Nazis and the Swastika appeared on the Eiffel Tower, the Louvre, and other prominent buildings. These events convinced the American people and Congress that a military build-up was essential.

Military manpower authorizations were increased and budgets skyrocketed as we began to man and equip a modern military. Concern began to be expressed that perhaps we should do more than merely depend upon voluntary enlistments to meet expected manpower needs. Enlistments had consistently filled vacancies through the 1930s because of the unemployment situation caused by the Great Depression.

By 1940, the situation had changed. War material orders were pouring in from Britain and France, our own military was growing, industry was rejuvenated, and jobs were opening. There was strong doubt enlistments would continue to meet the growing needs of congressionally enlarged military manpower authorizations. The Congress reacted in late June 1940 when the Burke-Wadsworth Bill was introduced prescribing conscription for military service.

Conscription

The Burke-Wadsworth Bill created a lot of debate and encountered strong resistance in the Congress and among the citizenry. Various groups in the US demonstrated against the bill and members of Congress voiced strong opposition. Nevertheless, the Bill was passed by Congress and, on 16 September 1940, President Franklin D. Roosevelt signed into law our first peacetime conscription act.

The law was officially known as "The Selective Training and Service Act of 1940," but it quickly became "The Draft" in popular parlance, although this terminology was deplored by the administrators of the act. With its passage, a new concern became important in American life and new words entered our vocabulary. Suddenly we had "draftee," "draft-dodger," and "4F" as common descriptors. We also learned we had "Draft Boards" and "registration."

The Bill authorized the conscription of male citizens for 12 months of military service. At the same time, it authorized the call-up of selected Reserve and National Guard personnel for 12 months of active service. Additionally, apart from the manpower element, the Bill authorized the US government to seize and operate industrial plants, if necessary, for the national defense.

The draft was administered by the Selective Service System and was eventually headed by General Lewis Hershey who ran the draft throughout the war. Local draft boards did the actual work involved and were manned by volunteers who received letters of appointment signed by the President.

Initially, all US males, ages 21 through 35, were ordered to register for the draft beginning 16 October 1940. Later, in November 1942, the registration age was lowered to 18 because of our entry into the war. All of this was amazingly well-received by the average citizen. Approximately three quarters of the men eligible for service thought the draft was probably a good idea and that it was necessary for the defense of the country.

Failure to register could be punished by up to 5 years in prison and up to a $10,000 fine. For the most part, the penalties were never needed because men registered and did their part more or less voluntarily. In fact, from October 1940 through June 1944, the only figures I have available show no more than 11,000 men were found guilty of registration delinquencies.

The first registration netted approximately 16 million men in the draft pool. The initial authorization for the draft was for 900,000 men to be placed in active military service for 12 months. To accomplish this, a lottery was held with the President and other dignitaries drawing numbers from a fishbowl type container. Those registrants with the selected numbers were the first eligible for conscription and service in the Army. The Navy and the Marine Corps chose not to accept draftees at this time and continued to rely on voluntary enlistments. Their reliance on volunteers continued until a national

decision in late 1942 to rely on the draft and end voluntary enlistments until the war ended.

The draft continued throughout the period of WWII. A new draft law was passed in February 1947 for the postwar years. In August 1941, when the initial law was expiring, Congress voted to extend the bill an additional 18 months. This measure was not easily passed, however, and the extension was approved only by a majority of one vote. After the Japanese attacked the US at Pearl Harbor, 7 December 1941, the law was extended indefinitely and the term of service was changed from 12 months to "for the duration"—meaning that all members of the military were to be retained until the war ended rather than serve a specified period.

During the war, more than 45 million men registered, more than 31 million were found eligible to serve, and about 15 million of those registered served for some period between the Fall of 1940 and the war's end in August 1945. There could be reasons for a registrant not serving and it was left to the wisdom of the local Draft Board to decide whether active service was or was not to be directed.

Draft Boards

The Draft Boards consisted of five men, usually of local repute, who volunteered to serve. They were, of course, not draft-eligible themselves because of age or other factors. They were not paid for their service but did it as a matter of patriotism and dedication. In general the activities of the Boards were not challenged and people accepted their work. Occasionally, of course, there was conflict. An individual could appeal a decision to a regional board, but these appeals were generally not successful.

There were complaints of favoritism in Board decisions. In some communities, because the Boards were not completely free of bias, there were allegations that the more affluent families kept their sons while the poorer ones lost theirs to the draft. In other communities, with some basis in fact, there were complaints that blacks were not drafted when eligible, but whites were. Without now arguing the ethics of conditions of that time, we must remember that American society was, to a large extent, segregated in the 1940s. There were strong feelings that the blacks should not be in the US military. So, sometimes the Boards would draft an eligible white and bypass an eligible black because of that racial bias. But, all in all, the Boards were equitable and rational in their actions. Their decisions were, to a large extent, not controversial.

Registration and Classification

Each man who registered was given a "draft card" and another new term came into the common vernacular. The draft card was supposed to be carried at all times and often served as an identification card or proof of age. For example, if a man were challenged in a bar—suspected of being underage—the draft card served to satisfy the challenge. Of course, after the draft age was lowered to 18, this use of the card was somewhat reduced.

Shortly after registering, each man had to complete a long and rather extensive questionnaire about himself. This was the basis for much of the later conscription action for him. The questionnaire helped the Draft Board establish its initial evaluation and priority for call-up.

The Induction Process

Military induction involved four processes after the initial letter of selection from the local Draft Board: (1) medical examination, (2) formal induction, (3) classification, and (4) initial assignment.

The medical examination consisted of evaluation in six primary physical characteristics: (1) stamina, (2) hearing, (3) eyesight, (4) motion and efficiency of upper extremities, (5) motion and efficiency of lower extremities, and (6) a neuropsychiatric evaluation. In each of these characteristics, there were four grades or levels of qualification. The first two grades were acceptable for general service and worldwide duty availability. Grade three was satisfactory for limited service which meant assignments short of worldwide utility. A person predominantly found to be in grade four was disqualified for military service. The classification of limited service was eliminated in July 1943 after which time the last two grades disqualified a man for military service.

The classification process involved application of a series of tests to determine each man's ability to learn, his intelligence, his skills and talents, and his affinity for certain trades. From this came a general assignment to a job grouping in the military. As far as practical, this led to the initial assignment.

The induction sites tried very hard to assign people according to the classified findings. However, the urgencies of the war manpower situation at the moment dictated assignments and sometimes the classification recommendation was not observed. After all, very few people would probably come through classification particularly qualified for infantry duty rather than mechanic, typist, cook, or whatever. Yet, infantry troops were constantly in strong demand—as were artillery and other combat duties in the Army and Navy. Nevertheless, not all registrants met infantry standards.

For example, 5 million draft age men were rejected as "unable to contribute" after 1943 based on the idea every member of the armed forces had to be able to do everything anywhere in the world. Thus, there was little or no consideration given to the practicality of selectively using slightly less than "perfect" people in jobs which did not demand perfect physical or mental condition. Nor was consideration given to using these "less than perfect" individuals in US sites allowing the more able-bodied to proceed overseas. Additionally, 1½ million were discharged from the Army and Navy for disability under the same rationale which demanded perfect physical condition regardless of job or location.

Deferrals

Great numbers of those registered were deferred from military service for various reasons:

- Occupational deferments in which the person was determined essential for farming, war production, civilian control agencies, or national defense programs.
- The person was needed to remain at home because of the reliance of certain dependents on their nearness.
- The person held a position as a government official or minister, or was an alien.
- The person was a conscientious objector.
- The person was unfit to serve in the armed forces for physical, mental, or moral reasons.

Conscientious objectors (COs) were of two general groups:

- Those who were members of long established peace churches, whose beliefs were well-known and had never been doubted.
- Those with a general religious opposition to war but without prior documented history of such beliefs. These individuals were suspect by many people.

The conscientious objectors were usually fairly treated by the general population. Occasionally, however, some were not. These were usually from the second grouping whose beliefs had not previously been expressed or documented. The COs were given the option of assignment in the military to noncombatant duties (usually in medical or chaplain functions), or unpaid civilian service in work camps established by the peace churches. Many of those who accepted military noncombatant duties performed exceptionally well. Many of them were in actual combat in their assignments and won medals for heroism and performance under fire. One, I believe, won the Medal of Honor.

In total, only 5500 conscientious objectors were imprisoned during the war. All others, and there is no firm figure for the total, either accepted one of the two assignments available or put aside their beliefs and permitted themselves to be drafted. Some did this because of the apparently overwhelming sense of disgust with the Japanese attack on Pearl Harbor and the information leaking out of Germany about Nazi treatment of non-Aryans. They seemed to want to do their part to defeat the Axis powers and Japan.

The availability classification of a man after his initial evaluation was one of the following:

- Category 1 Eligible for active service.
- Category 2 Deferred for work essential reasons.
- Category 3 Deferred for dependency.
- Category 4 Deferred for physical, mental, moral, or religious reasons.

Each category had subsets to describe specific conditions. For example, the "4F" mentioned earlier meant, generally, the man had been deferred from active service because of some aspect of his physical condition. For many who were drafted, the "4F" identification of some of their buddies back home was a sore spot. Often there was no obvious physical disability and this caused considerable questioning about fairness and logic.

A lot of the men who were drafted, and particularly those who were overseas and in combat, had serious questions about some professional sports figures who were classed "4F" yet who continued to participate in sports. They had specific gripes about football and baseball players, and boxers. Many letters to the editors of service newspapers, and American magazines, asked how this could be. The letters obtained action and, in the middle of the war, the US military services began to accept men with physical defects which would not really interfere with their active military service.

This not only involved the professional athlete, it also involved thousands of other men who had been deferred for conditions below established military standards. As a result, later in the war, the services had to begin extensive programs to correct many physical and dental problems of these men. While initially very expensive, overall it served the person and the country very well.

The same situation existed for those unable to read and write. Early in the draft, these men had been deferred because they could not meet stiff standards requiring those skills. Later in the war, bowing to home-front pressures, the standards were changed and illiterates were included in the draft. The services began massive programs to teach these men their basic 3R skills. Again, though expensive, the action proved greatly beneficial to the individuals and to the country.

Manpower Strength

The table portrays the military manpower strength of the United States at three points in time from late 1939 to late 1945.

In total, close to 18 million personnel served in the US military during WWII. Of these, 62% were drafted. In fact, there were almost 18 million examined for induction and about 6.5 million of them were found to be unqualified to serve for one reason or another. The average time in service was 33 months. More than 7.5 million served overseas averaging a bit more than 16 months in foreign assignments. Almost 40% of those who served in enlisted status were in rear echelon assignments such as administrative, technical, support, and manual labor classifications.

MILITARY MANPOWER - USA

	US Army	US Navy	US Marines	Total
1939	189,839	125,202	19,432	334,473
1941	1,462,315	284,427	54,359	1,801,101
1945	8,267,958	3,380,817	474,680	12,123,455

Note: Army figures include the Army Air Forces.

Conclusion

We have only touched the surface of manpower programs of the United States in WWII. Even so, we have been able to briefly mention a major event in American life—THE DRAFT. It affected the lives of so many people and involved so much effort, there were bound to be mistakes and errors. Nevertheless, despite the blunders, despite the errors, the hard work and dedication of thousands of volunteers manning local and regional draft boards made the system work reasonably well.

Overall, the Selective Service System did its job satisfactorily and met the country's needs for wartime military manpower. And, overall, it did that massive job with a high degree of fairness and equity.

The manpower element of the country's logistics system did its job, enabling the other elements of logistics to function effectively and successfully.

It would pay us all to consider the wartime manpower needs of the country as we think and plan for industrial and military readiness and mobilization in the event of another national emergency. Manpower is the first fundamental of logistics.

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studies, compared with 67% Air Force wide. Comparisons won by in-house MEOs have been economical in dollars and manpower, as well as effective in providing mission support.

Conclusion

Where manpower resources are needed to support other Air Force missions, well-managed contracts provide an excellent alternative to performing civil engineering functions in-house. These functions can be economically operated under contract or with in-house personnel but, in either case, intelligent management is needed for truly cost-effective mission support. For contracts, detailed and accurate performance work statements, backed by a thorough quality assurance evaluation system, are the keys to success.

This is the first of two articles (second one to be published in Fall 1988 issue) which discusses the issue of contracting-out of base services.

Coming in the Fall Issue

- Contractor-Operated Parts Stores: Is Change Overdue?
- Scheduling Tactical Aircrews to Meet Flying Requirements
- Quality: The Elusive Challenge

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